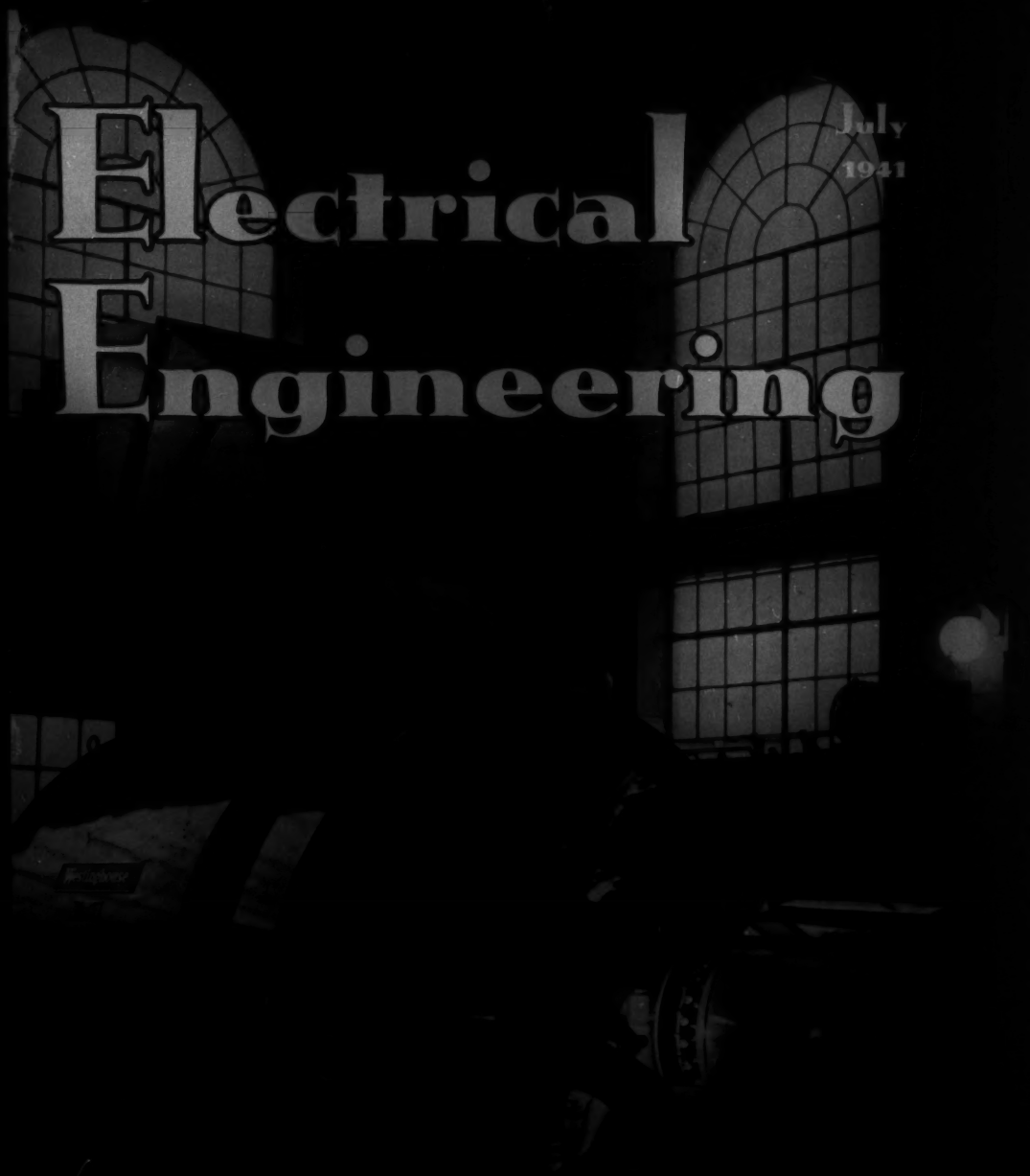
Electrical Engineering

July
1941

Vol. 60
1941



Published Monthly by the
American Institute of Electrical Engineers

NOW—FOR THE FIRST TIME

Low-price Direct-current Recorders

Obtaining a permanent record of a tube plate current with a CF-2 d-c milliammeter

for Low-range and High-sensitivity Measurements

Milliammeters
Microammeters
Millivoltmeters
and
Ammeters
Voltmeters

THIS new line of instruments (Type CF-2) makes it possible to obtain permanent records of circuit conditions where, previously, only indicating instruments, or expensive recording equipment, were available.

You will find these instruments ideal for electronics work because of their low power consumption.

THEY'RE INKLESS

There's no ink to spill, blur, or freeze. You are sure to obtain accurate records in temperatures from —10F to 120F, and rapidly fluctuating loads will not cause "painted" charts.

The CF-2 recorder is small, sturdy, accurate within 2 per cent, and readily portable—it weighs only 12 pounds. A reliable Telechron motor feeds the chart at either 1, 2, or 3 inches per hour.

For a-c measurements, the companion Type CF-1 instrument is available.

Get complete information from the nearest G-E Office. Ask for our Bulletin GEA-3187, General Electric, Schenectady, N. Y.

APPLICATIONS

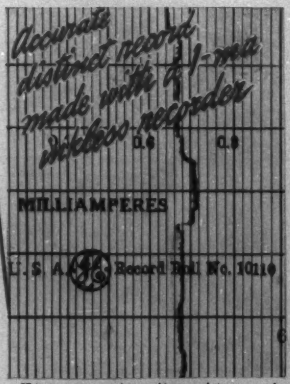
Here are just a few of the many possible uses for these recorders:

1 Development work—permanent records of circuit conditions will minimize the need for cut-and-try work, and will facilitate the duplication of test set-ups.

2 Smoke density—a recorder, used with auxiliary equipment, is an inexpensive way to obtain permanent records of smoke density, so that you will have proof for city inspectors.

3 Vacuum-tube circuits—to record plate current or voltage.

4 Moving vehicles—to study battery and generator performance.



CF instruments record by making one dot per second. This record was made with a relatively constant current. On fluctuating circuits the record may not be continuous, but the density of the dots gives an indication of the average current or voltage.

TYPICAL CHARACTERISTICS OF A POPULAR RATING

Range	0 to 1 ma
Resistance	16 ohms, approx.
Response time	3 sec. approx.
Dimensions	8 9/16 by 10 9/16 by 5 31/32 in.
Scale length	3 1/2 in.
Chart speed	3 in. per hour

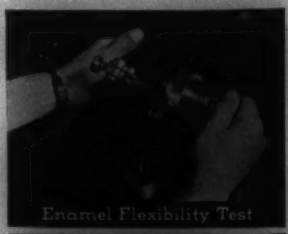
GENERAL ELECTRIC

605-18

Even during today's heavy production schedules

all Belden enameled wire must pass these 6 severe tests of "BALANCED" Insulation

Film Thickness Test


Enamel Flexibility Test

Enamel Adhesion Test

Copper Softness Test

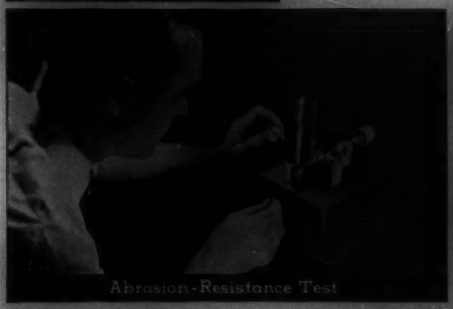
The tremendous demand for magnet wire has not altered the production standards of Beldenamel. As always, Beldenamel wire has "balanced" insulation. These six vital characteristics are always in "balance":

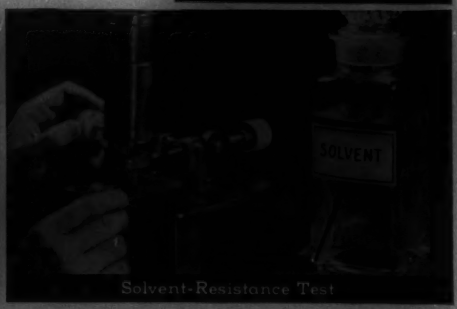
1. Uniform film thickness
2. Adherence
3. Abrasion-resistance
4. Solvent-resistance
5. Dead-softness of wire
6. Flexibility

Only "balanced" insulation stands up under tough winding conditions or in long years of severe service. Only "balanced" insulation provides the lowest over-all winding costs.

The easiest and cheapest way to safeguard your winding schedules (and also your product) is to specify "BALANCED" insulation. If you wish complete data on the Belden "balanced" insulation tests, we shall be glad to mail this information on request.

Belden Manufacturing Co.
4635 W. Van Buren St., Chicago, Ill.


Abrasion-Resistance Test



Solvent-Resistance Test

Belden Magnet Wires

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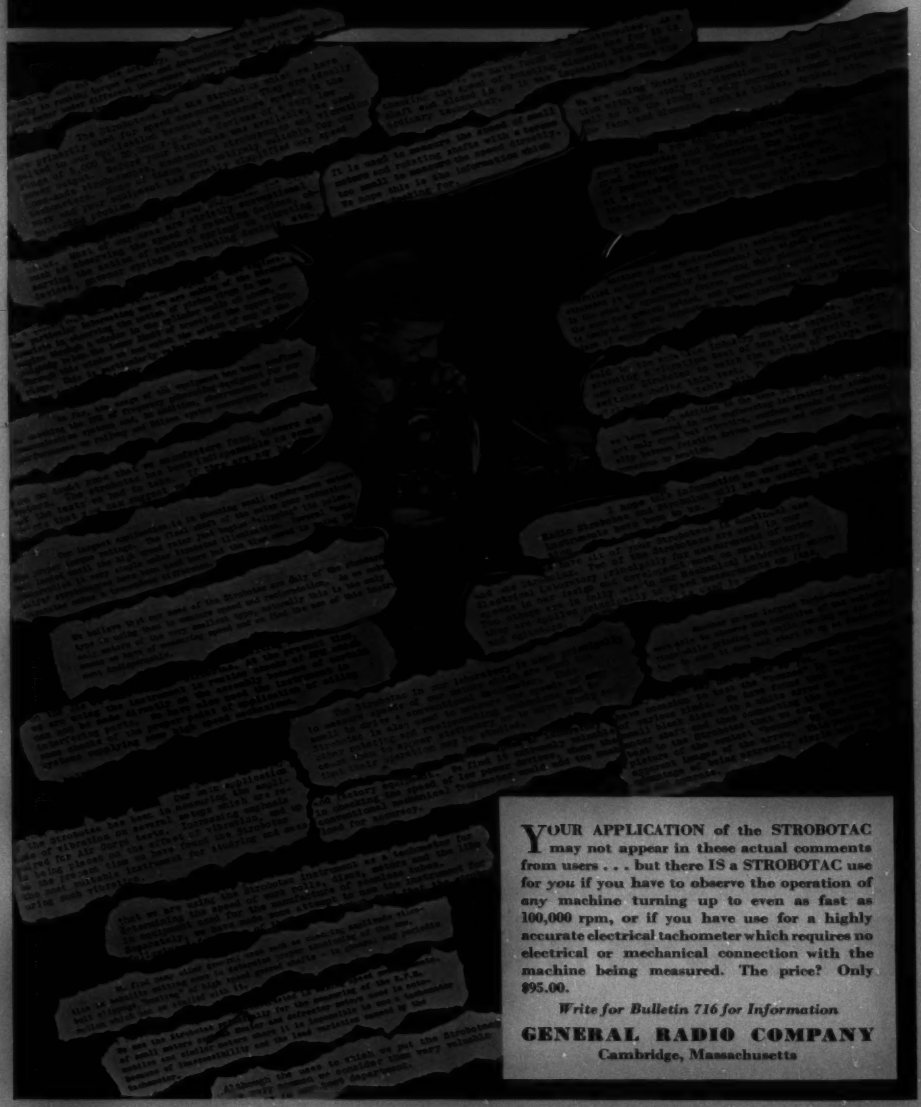
Here's what the users say... about the STROBOTAC



YOUR APPLICATION of the STROBOTAC may not appear in these actual comments from users . . . but there IS a STROBOTAC use for *you* if you have to observe the operation of *any* machine turning up to even as fast as 100,000 rpm, or if you have use for a highly accurate electrical tachometer which requires no electrical or mechanical connection with the machine being measured. The price? Only $95.00.

Write for Bulletin 716 for Information

GENERAL RADIO COMPANY
Cambridge, Massachusetts

Look at it from ANY ANGLE

RELIABLE PERFORMANCE

The continued choice of Hazard Keystone Cable by so many companies . . . for more than 40 years . . . testifies to the complete assurance you have of obtaining reliable, efficient high tension service.

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Stubbornly resistant to corona . . . moisture . . . and heat, Hazard Keystone Insulated Cable also possesses excellent aging qualities. You can count on it to deliver the long cable life that means distribution economy.

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Hazard Keystone Cable is priced to deliver an extremely high quality of service at low cost. It will pay you to let us study your requirements.

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for HIGH TENSION SERVICE

You'll find Hazard Keystone Cables particularly efficient and economical for:

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Station Control Wiring — Station Cables — Aerial Cables
Apparatus and Equipment Leads — Vertical Riser and Shaft Cables
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HAZARD INSULATED WIRE WORKS
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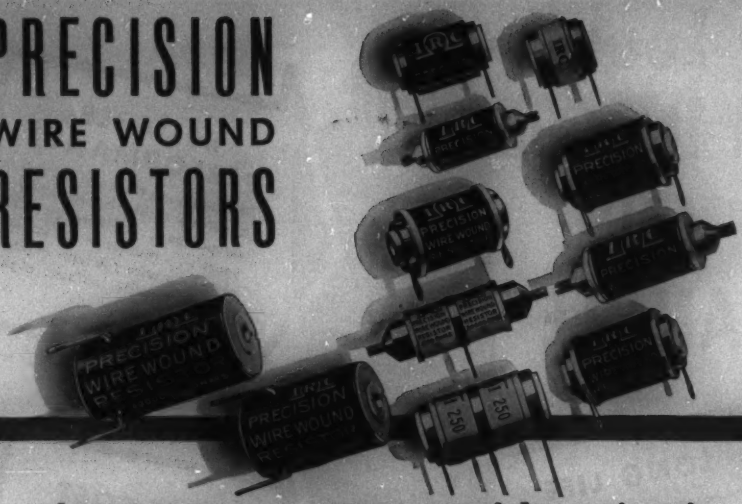
PRECISION WIRE WOUND RESISTORS



The Answer to Many Bridge Circuit Resistance Requirements

Never has there been such a concerted development of electrical equipment requiring resistors for bridge and similar circuits where the call is for greater accuracy and lower temperature co-efficient than heretofore available in production quantities.

IRC Precision Wire Wound Resistors were designed for such purposes. They are made to a standard tolerance of ±1% or to as low as 1/10 of 1% on special order. They have an extremely low temperature co-efficient for stable operation over a temperature range from −30° C. to 100° C. They are impregnated against humidity and other atmospheric conditions. They are available in the most complete line of inductive and non-inductive types, shapes, sizes and terminals on the market today.

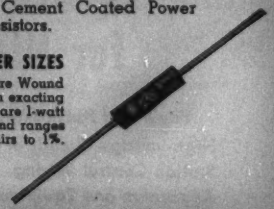
Thousands of these units used in a wide range of equipment from voltmeter multipliers for sea coast duty to geophysical instruments used in tropical climates prove their dependability under the most exacting conditions.

Whatever your resistance requirements, it pays to ask IRC. IRC engineers will welcome the opportunity to cooperate. They are backed by the world's largest line of fixed and variable resistors. Their recommendations are based on many years of specialized experience in dealing with practically every type of resistance problem.

Write for IRC Resistance Engineering Data Bulletin No. IV including both IRC Precision and Cement Coated Power Wire Wound Resistors.

MAXIMUM PROTECTION • CLOSE TOLERANCES • SMALLER SIZES

This is an actual size view of an IRC Type BW ½-watt Insulated Wire Wound Resistor — a compact, well-protected unit that can often be used in exacting applications where space is at a premium. Other Type BW sizes are 1-watt and 2-watts. Tolerances available to as close as 2%. Some sizes and ranges can be supplied to even closer tolerances and in matched pairs to 1%.



IRC

INTERNATIONAL RESISTANCE CO.

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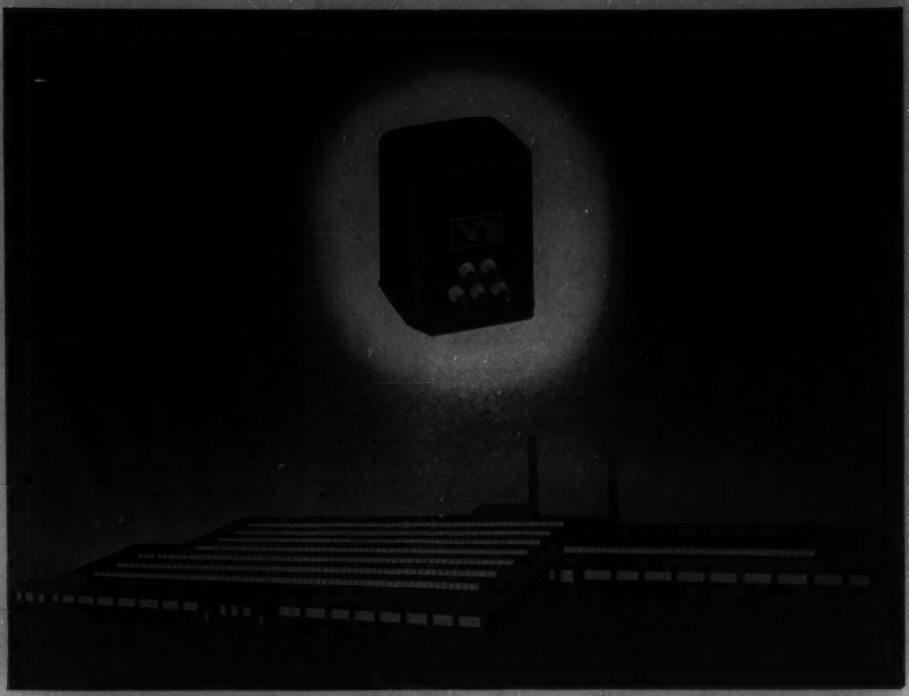


ELECTRICAL ENERGY

Converted to usefulness with Accuracy by transformers that reflect their makers integrity . . .

The new, completely modern Chicago Transformer plant with its thoroughly equipped laboratories—experienced engineers, workmen and large stock of parts are your assurance of speed, accuracy, and versatility in obtaining the right transformers.

The Chicago Transformer Corporation is geared to the most efficient production of air-cooled and dry-type transformers, up to 12 KVA in size . . . Given the application and the results expected, Chicago Transformer Corporation can give you transformers to fit almost any need.

CHICAGO TRANSFORMER
CORPORATION
3501 WEST ADDISON STREET • CHICAGO

290 tons per week of steel wire is annealed, to a dead-soft condition, in these Lee-Wilson furnaces used by Wickwire Bros., Inc., Cortland, N. Y.

INSTALLING NEW FURNACES?
Let Micromax Control Them, And Tell You How Well They're Performing!

A battery of annealing covers went to work a few months ago for Wickwire Bros., Cortland, N. Y., makers of wire and woven-wire products.

These furnaces are quick to heat, highly uniform in internal temperature, and responsive to automatic control. They have every quality needed to do a good job, provided they are properly controlled and are handled by skilled workmen, fully informed as to temperature and other conditions inside.

On the pyrometers, no chances are taken. Micromax recording controllers are used, directing the action of the fuel valves. The Controllers are connected to couples at top and bottom of charge, and at the firing tubes. Control is based on the top couple only, but its temperature, as well as that of the other two, is recorded on the one chart. Thus, the Company profits by the speed and responsiveness of the equipment, to put the whole temperature story in one place. This is a great advantage, both in beginning to use a new furnace and in maintaining uniform anneals from day to day and season to season.

Micromax has completely solved this problem for Wickwire Bros. Inc., and can do as much for you, in any controllable furnace. For further information, write for catalogs.

"Paid To Take No Chances" Says Plant Superintendent

We can't, of course, tell his name, but the superintendent of a big Pennsylvania manufacturing plant commented in a most interesting fashion the other day, when discussing his general policies in selection of equipment for his plant. Your correspondent simply asked him why he had standardized on Micromax pyrometers, and that set him off.

"I'm just a hired man here," he said, in effect, ". . . a manager. I employ the rest of the help, and I keep the supplies bought, and the machinery running, and hold the quality of the product up to snuff. As long as those things get done, my job suits me, and I suit the stockholders."

One of the Micromax Controllers selected by the superintendent who "takes no chances."

"Now, to do those things, I have to have policies. And my main policy is to take no chances I can avoid. The President told me, when he hired me, that I would be paid not to take chances, and that's my guiding star."

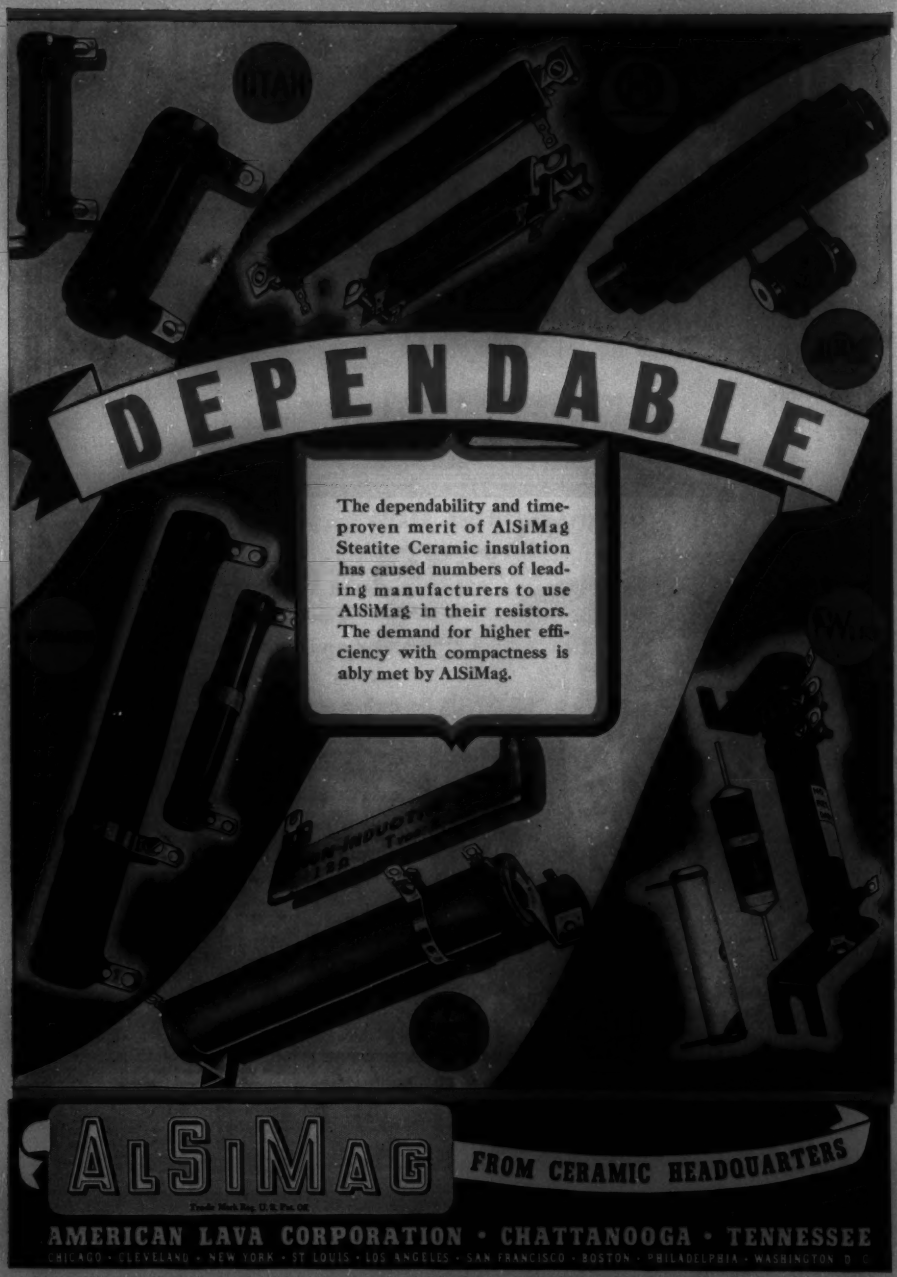
"So, when I hire a man, I pick the one who is surest to do his job right, and if he has a good name with his last boss, that just about sells him to me. The same goes for equipment. You know, in pretty nearly every line there's one product or one maker who is generally considered 'tops'. I look for that 'tops' when I have to buy something, because when I find it, I'm not taking needless chances."

"Look at the name-plates on those presses. Look on the motors, and the furnaces, and the cranes, and the lighting fixtures, and even the electric bulbs . . . everyone knows they're 'tops,' all of them. And that's why Micromax gets my pyrometer business. I take no chances . . ."

LEEDS & NORTHRUP COMPANY, 4962 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

Jrl Ad ENT 0600C(23) MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES


DEPENDABLE
The dependability and time-proven merit of AlSiMag Steatite Ceramic insulation has caused numbers of leading manufacturers to use AlSiMag in their resistors. The demand for higher efficiency with compactness is ably met by AlSiMag.
AlSiMag
Trade Mark Reg. U. S. Pat. Off.
FROM CERAMIC HEADQUARTERS
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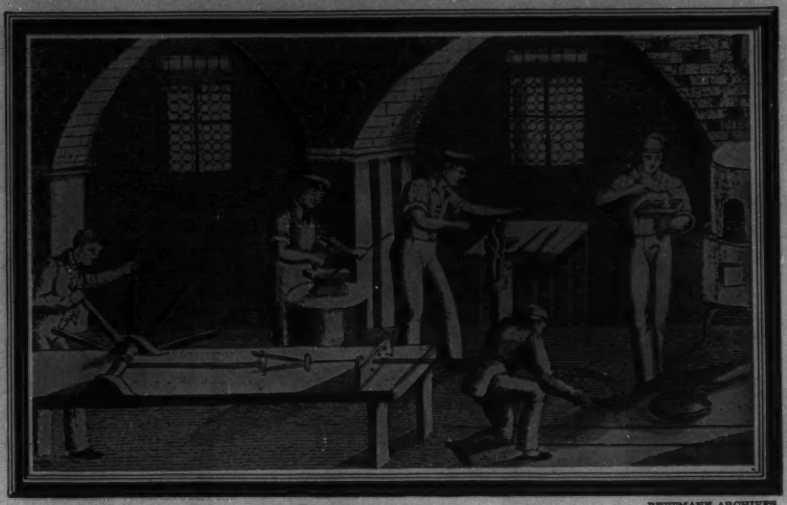
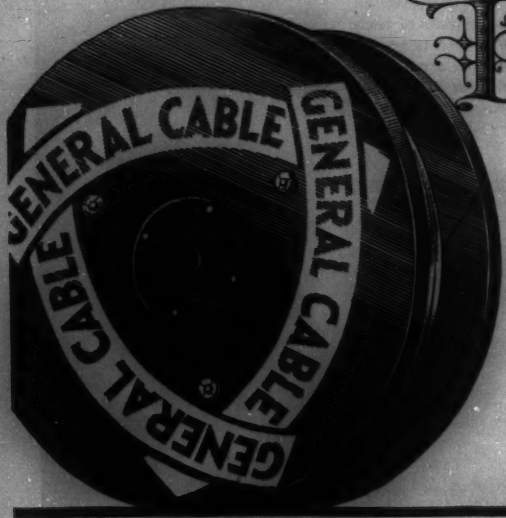


Engraved in 1828, this record of early wire manufacture would seem to indicate that straight-line production was even then in vogue.

BETTMANN ARCHIVES



RAPID ADVANCES in the use of electricity for light, power and communications have greatly complicated the art of cable manufacture. Constant research in both cable design and production methods have, however, maintained General Cable Corporation in a preeminent position in the industry.

GENERAL CABLE

BARE and INSULATED WIRES and CABLES for EVERY ELECTRICAL PURPOSE

General Cable Corporation Sales Offices: ATLANTA • BOSTON • BUFFALO • CHICAGO • CINCINNATI • CLEVELAND • DALLAS • DETROIT • HOUSTON KANSAS CITY (MO.) • LOS ANGELES • NEW YORK • PHILADELPHIA • PITTSBURGH • ROME (N.Y.) • ST. LOUIS • SAN FRANCISCO • SEATTLE • WASHINGTON (D.C.)

NOW

SPIRAKORE

INSTRUMENT TRANSFORMERS

OUTDOOR C.T.'s — 2 SIZES

Type KF-311
23 kv
(supersedes Type KF-310)

NOTE THESE FEATURES

LIGHTER WEIGHT

23-kv unit reduced 10%
34.5-kv unit reduced 16%

SMALLER SIZE

Both units reduced 3 in. in diam
(34.5-kv unit also reduced 3 in. in height)

PYRANOL FILLED

No fire hazard, no sludge
(also available oil filled)

HIGH ACCURACY

Well within the highest accuracy classification $\frac{1}{2}X$, $\frac{1}{2}Y$, $\frac{1}{2}Z$
Suitable for relaying or metering

Type KF-316
34.5 kv
(supersedes Type KF-315)

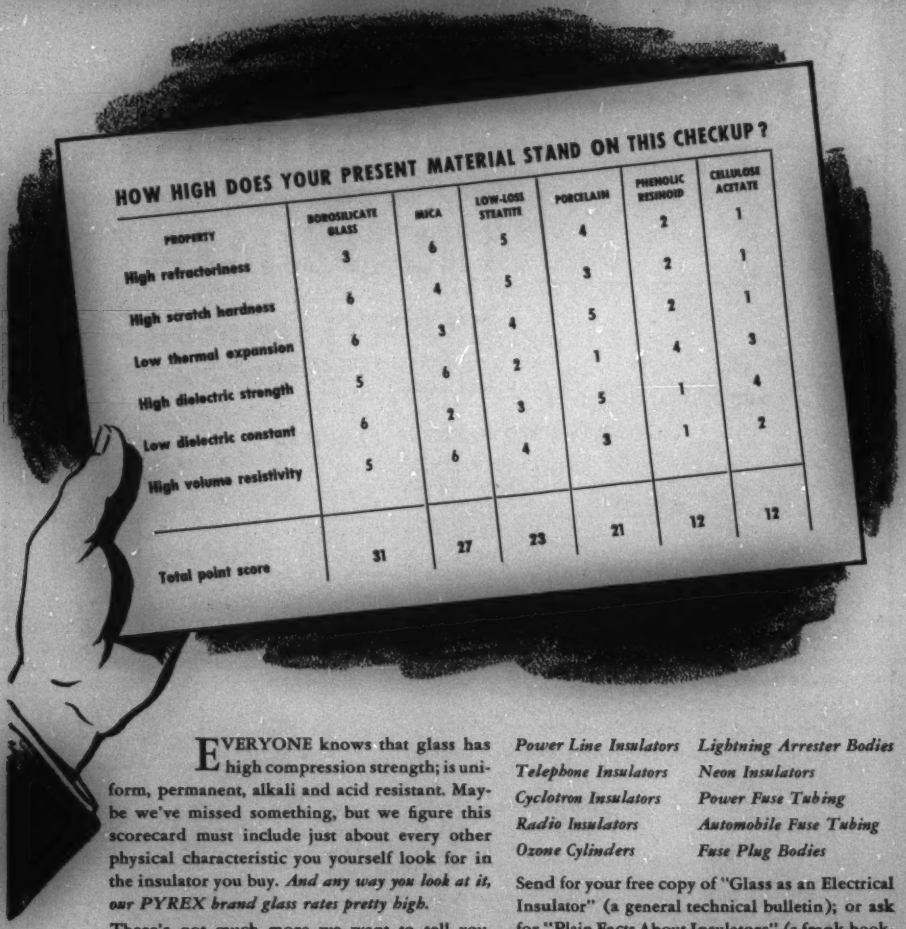
THE Spirakore design, so successful in G-E distribution transformers, is used in these new outdoor current transformers. The reductions in size and weight are due primarily to this unique core construction.

These Spirakore outdoor units are of the porcelain-shell type. Their high accuracy under over-current conditions makes them ideal for relaying as well as metering.

Get in touch with the nearest G-E office for more information and assistance in applying these transformers. General Electric, Schenectady, N. Y.

GENERAL ELECTRIC

Is this how you judge an insulator?



PROPERTY	BOROSILICATE GLASS	MICA	LOW-LOSS STEATITE	PORCELAIN	PHENOLIC RESINOID	CELLULOSE ACETATE
High refractoriness	3	6	5	4	2	1
High scratch hardness	6	4	5	3	2	1
Low thermal expansion	6	3	4	5	2	1
High dielectric strength	5	6	2	1	4	3
Low dielectric constant	6	2	3	5	1	4
High volume resistivity	5	6	4	3	1	2
Total point score	31	27	23	21	12	12

EVERYONE knows that glass has high compression strength; is uniform, permanent, alkali and acid resistant. Maybe we've missed something, but we figure this scorecard must include just about every other physical characteristic you yourself look for in the insulator you buy. *And any way you look at it, our PYREX brand glass rates pretty high.*

There's not much more we want to tell you, except this: PYREX brand glass is already contributing to the electrical industry in these ten important ways:

Power Line Insulators
Telephone Insulators
Cyclotron Insulators
Radio Insulators
Ozone Cylinders
Lightning Arrester Bodies
Neon Insulators
Power Fuse Tubing
Automobile Fuse Tubing
Fuse Plug Bodies

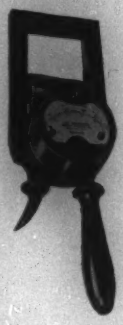
Send for your free copy of "Glass as an Electrical Insulator" (a general technical bulletin); or ask for "Plain Facts About Insulators" (a frank booklet about power line problems). Simply write Corning Glass Works, Insulation Division, O'Brien St., Corning, New York.

"PYREX" is a registered trade-mark and indicates Manufacture by Corning Glass Works

CORNING means Research in Glass

Pyrex Insulators
BRAND

Ferranti



LOW COST CLIPON AMMETER

DUAL RANGE 0–100/500 AMPS

..Perfect Balance
..Light Weight
..Completely Insulated Jaws
..±2% Accuracy
..Large 2¼" Square Opening
..Long Open Scale
..50 Scale Divisions
..10 Years' Proven Service

ONLY $80. LIST

ALSO

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0–10/25/100/250/1000 AMPS.

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NEW HIGH ACCURACY PORTABLE

VOLTMETER

..0–150/300/750 Volts
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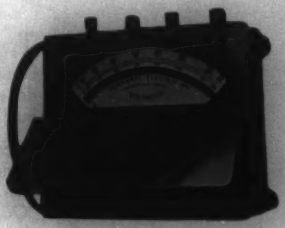
..½ of 1% Accuracy
..AC-DC
..Hand Calibrated Mirror Scale
..150 Scale Divisions
..Frequency 15–135 cps.
..Hinged Cover with Leather Carrying Handle
..Light Weight — Robust Construction
..Conforms to A.I.E.E. and N.E.M.A. Specifications

MADE IN U.S.A.

ONLY $66. LIST



Solid leather, plush-lined, carrying cases for any of these instruments

LIST $15.

Mail the Coupon for free trial

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Please send me for 10 days' free trial, without obligation:

1.—0–100/500 A. Dual Range ClipOn Ammeter
With Case ☐
Without Case ☐

2.—0–10/25/100/250/1000 A. Multi Range ClipOn Ammeter
With Case ☐
Without Case ☐

3.—0–150/300/750 V. Triple Range Portable Voltmeter
With Case ☐
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Name .....
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RADIO • ELECTRICAL • INDUSTRIAL
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Solar reliability under all conditions has earned preference in the Armed Service Branches of our Government. This "Quality Above All" construction is also available to all capacitor users.
For satisfaction — for safety — make Solar your standard!
Literature on request . . . Engineers on call
Solar Mfg. Corp.
Bayonne, New Jersey
Quality above all

Electrical Engineering

Registered U. S. Patent Office

for July 1941—

The Cover: The synchronous condenser at the Gorge steam plant of the Ohio Edison Company is cooled by electrostatically cleaned air

Photo courtesy Westinghouse

Making Democracy Work	...Howard Coonley	...313
ECPD Should Look Ahead	...Robert E. Doherty	...318
The Old Order Changes but Men Run True to Form	...Royal W. Sorensen	...322
Applications of High-Voltage Fluorescent Tubing	...Julian A. McDermott	...327
Miscellaneous Short Item: Low-Voltage Cords Eliminate Shock, 330		
Institute Activities		...331
Of Current Interest		...358

Transactions Section *(Follows EE page 366; a preprint of pages 763–810 of the 1941 volume)*

Large Electric-Arc Furnaces—Performance and Power Supply	...B. M. Jones, C. M. Stearns	...763
The "Electrogear"—A New Electromechanical Vehicle Drive	...Ernst Weber	...770
Mechanical Strength of Cellulose Insulation	...F. M. Clark	...778
Rotor-Bar Currents in Squirrel-Cage Induction Motors	...J. S. Gault	...784
Short Time and Intermittent Ratings and Applications	...R. E. Hellmund	...792
Atmospheric Variations and Apparatus Flashover	...P. H. McAuley	...798
Volt-Time Areas of Impulse Spark-Over	...J. H. Hagenguth	...803

VOLUME 60 FOUNDED 1884 NUMBER 7

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High Lights • •

ECPD. Engineers' Council for Professional Development, joint agency of several national engineering bodies including AIEE, organized "to enhance professional status of the engineer," has completed its eighth year. The greatest single accomplishment of ECPD has been the survey and accrediting of more than 500 engineering-college curricula conducted by its committee on engineering schools. In a report to the board of directors of the constituent bodies, the chairman of ECPD outlined its accomplishments to date, stating that ECPD is the only body now in position to deal effectively with the broad problem of professional development (*pages 318–21*). In his current message to the Institute membership, President R. W. Sorensen also discusses ECPD, particularly its accrediting program (*page 331*).

June Supplement. The June 1941 Supplement to Electrical Engineering—Transactions Section, first midyear supplement to be issued under the revised publication policy, will contain 39 technical papers and the discussions of these papers and those preprinted in the TRANSACTIONS sections of ELECTRICAL ENGINEERING from January to June 1941 inclusive. Abstracts of most of these papers have appeared in previous issues; the remainder are abstracted in this issue (*pages 334–5*).

Flashover and Atmospheric Variations. While standards for insulation of electrical apparatus recognize that the electrical breakdown strength of air depends upon air temperature, pressure, and moisture content, the effect of extreme conditions is not always appreciated; the degree to which present standards and application practices cover the range of variation found in actual service has been analyzed (*Transactions pages 798–803*).

Short-Time and Intermittent Ratings. Temperature rises permissible for short-time and intermittent ratings of apparatus have been compared with those permissible for continuous ratings and methods suggested for applying short-time ratings to various typical classes of intermittent load conditions, with means of co-ordinating the ratings of motors and generators with those of auxiliary devices for each class of conditions (*Transactions pages 792–8*).

New Vehicle Drive. The "Electrogear", recently developed electromechanical transmission for gas and Diesel-engine cars of all types, has as its operating principle a differential action between direct mechanical power transmission and a generator-motor system, interlinked by means of a permanently engaged planetary differential gear (*Transactions pages 770–7*).

Spark-Over Characteristics. Classification of impulse wave shape shows that impulse spark-over characteristics of electrodes with nonuniform fields cannot be represented by volt-time curves, but must be represented by volt-time areas of considerable extent; insulation must be co-ordinated on the basis of these areas (*Transactions pages 803–10*).

High-Voltage Fluorescent Tubes. The increasing number and variety of applications of high-voltage fluorescent tubing, both alone and combined with other light sources were described at the AIEE winter convention conference on fluorescent lighting (*pages 327–30*); other scheduled discussions from the conference and technical session appeared in the June issue.

Strength of Cellulose Insulation. Factors influencing the deterioration of cellulose insulation when exposed to temperatures above room temperature have been gauged from a study of the change in tensile strength; the deterioration has been shown to be a function of two distinct chemical reactions: oxidation and pyrochemical decomposition (*Transactions pages 778–83*).

Design for Democracy. The responsibility of engineers, as well as that of leaders of industry and all other citizens, to recognize their interdependence and to do their part in the "engineering job" of making democracy work was emphasized in an address at the general session of the recent AIEE summer convention (*pages 313–18*).

Rotor-Bar Currents. An analysis has been made of the rotor-bar currents in squirrel-cage induction motors for the purpose of extending the theory of induction motors to include the computation of these currents and to show the effect of the rotor-current harmonics upon the efficiency of the motor (*Transactions pages 784–91*).

Electric-Arc Furnaces. Increasingly used for producing high-grade alloy steels, electric-arc furnaces are desirable loads for power systems but must be so connected that the violent and rapid load swings will not interfere with other local services or reflect back into the system to affect other equipment (*Transactions pages 763–9*).

President's Address. Changes in the AIEE since its founding, and the part of engineers and the engineering societies in this changing world order were the main themes of the presidential address delivered according to custom at the summer convention by President Royal W. Sorensen (*pages 322–6*).

Directors' Report. Included in full in this issue is the annual report of the AIEE board of directors to the Institute membership for the year ending April 30, 1941. It contains brief reports of the activities of the various committees and the usual financial tabulations (*pages 336–50*).

New AIEE Officers. Among other items of business at the annual meeting of the AIEE held during the summer convention at Toronto, Canada, was the announcement of new officers elected for the administrative year beginning August 1, 1941 (*page 333*).

Pacific Coast Convention. With Yellowstone Park as its location, the forthcoming AIEE Pacific Coast convention to be held August 27–30, 1941 will combine scenery with technical sessions (*page 332*).

Letters to the Editor. Indicative of the growing concern of the Institute's membership with the economic and social aspects of engineering matters are several letters to the editor in this issue, commenting on articles on these themes in recent issues of ELECTRICAL ENGINEERING; other letters deal with matters of a more strictly technical nature (*pages 362–5*). These columns provide a forum for opinion to which members are always urged to contribute.

Coming Soon. Among special articles and technical papers currently in preparation for early publication are: an article describing powerful ultraviolet light sources and their industrial applications by J. H. Laub (M'36); an article on operating results of PCC cars by G. M. Woods; an article discussing emergency lighting practice and "black-out" precautions by S. G. Hibben (A'34); a review of present understanding of and experience with lightning by C. F. Wagner (F'40) and G. D. McCann, Jr. (A'38); a paper describing the way modern motors serve city transit systems by W. J. Clardy (M'39) and C. A. Atwell (A'41); two papers on the theory of the brush-shifting a-c motor by A. G. Conrad (M'40); F. Zweig (Enrolled Student), and J. G. Clarke (A'41); a paper describing a short method for evaluating determinants and solving systems of lineal equations with real or complex coefficients by P. D. Crout; a paper on the effect of sapphire-crystal orientation on the wear of bearings of watt-hour meters by J. H. Goss (A'35); a paper on overvoltages in polyphase induction motors during single-phase operation by C. Macmillan (M'35) and G. K. Carter (A'36); a paper describing a new mercury rheostatic element for regulation and control by K. A. Oplinger (M'39); a paper on measuring prebreakdown currents in dielectrics with a cathode-ray tube by H. H. Race (F'39); a paper describing an ampere-squared-second recorder by T. A. Rich (A'41); a paper presenting an engineering viewpoint on the dielectric strength of glass by E. B. Shand (M'29); a paper on a photographic study of a-c arcs in flowing liquids by J. Slepian (F'27) and T. E. Browne, Jr. (A'36); and a paper on the determination of magnitude and phase angle of electrical quantities by E. A. Walker (M'41).

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Making Democracy Work

Howard Coonley

SOME 30 years ago, in a famous study of "The Frontier in American History," Frederick J. Turner wrote these prophetic words as to the future of private enterprise in America:

"We can understand the reaction against individualism and in favor of drastic assertion of the powers of government. Legislation is taking the place of the free lands as the means of preserving the ideal of democracy. But at the same time it is endangering the other pioneer ideal of creative and competitive individualism. Both were essential and constituted what was best in America's contribution to history and to progress. Both must be preserved if the nation is to be true to its past. It would be a grave misfortune if these people so rich in experience, in self-confidence and aspiration, in creative genius, should turn to some Old World discipline of socialism or plutocracy, or despotic rule, whether by class or by dictator."

That reaction against 19th-century individualism, and even against democracy as the guardian of individual rights, has gathered momentum since the World War. It has become a phase of a revolutionary movement spreading around the world, for the restoration of absolute power to central governments and a modern streamlined model of the omnipotent, coercive, superhuman state.

We have watched that movement in the Old World. There in some countries the World War broke down autocracies resting on a landed nobility; but the attempt to establish democracies offhand, without experience in the ways of democracy, resulted merely in the substitution of one form of despotism for another. The people reacted to the vagaries of feeble democracy by following ambitious leadership which set up totalitarian governments. The interval of democracy was but six months in Russia, fourteen years in Germany. Then the ambition of arbitrary rulers led them to use their new power for external aggression. They proceeded to overwhelm their neighbors—both democracies which did not unite for self-defense and other countries where democracy had hardly got a foothold. On the continent of Europe 24 out of 27 nations have succumbed to totalitarian rule, from within or without, and the three small democracies still independent retain but a precarious independence.

In the United States we have been conducting our experiment in democracy for more than 150 years—endeavoring to develop it so as to safeguard individual freedom and promote the common welfare. Canada has had a similar experience. Through all the changes involved in transforming a nation mainly agricultural into a nation highly industrialized, we have kept the ideal of creative and competitive individualism as an essential element of democracy and a guaranty of continuous economic progress.

Address presented at the "general" session of the AIEE summer convention, Toronto, Ontario, Can., June 19, 1941.

HOWARD COONLEY is chairman of the board, Walworth Company, Inc., New York, N. Y., and chairman of the executive committee, National Association of Manufacturers.

◆ ◆ ◆ All too thoughtlessly and all too commonly democracy has come to be regarded as being a one-way proposition—just an intangible "something" which somehow automatically establishes and guards individual freedom, individual *rights*, and individual *privileges*. That this careless point of view may be understandable makes it no less tragic and at least potentially devastating. True democracy connotes co-operation and *inter*dependence—a definite *responsibility* for each citizen if there is to be any democracy. There must be a general awakening—"or else!"

◆ ◆ ◆ As further evidence of and encouragement for this essential awakening, another prominent leader of American industry here challenges the engineering profession to rally to the moral and spiritual as well as physical defense of "the heritage of freedom that has given wide range to the engineering profession and made possible its great achievements". Mr. Coonley specifically suggests ten points for consideration and action.

◆ ◆ ◆ Eternal vigilance is the minimum price of true democracy.

We have looked on the state mainly as the protector of individual rights—of rights individuals may exercise by themselves or in voluntary association with others. Our forefathers set up the state, and we maintain it ourselves, as our collective agency to preserve our own freedom from infringement by any "pole cats and foxes" among us, as Locke said, and from any external aggression. We delegate to government also, as an agency freely chosen and periodically accountable to us, such other services for the common welfare as we find we cannot provide so well for ourselves through private agencies. We have not endowed these governments of our own creation with any superhuman qualities. It has not been the American way, in the United States or Canada, to turn over to them full direction of our cultural, economic, or domestic lives—to let them determine what we may read, say, hear, or think, in what occupation or enterprise we may engage, where and how we may live.

But a severe and prolonged economic depression has spread doubt of the efficiency of our system of free institutions—of our own ability to make free institutions work for the maximum economic security for all the people. Fortunately, however, we are accustomed to social change by evolution rather than revolution, by voluntary co-operation rather than arbitrary force. If we are to escape an evolutionary development toward such systems as revolution and war have been setting up in Europe—which submerge all individual freedom in the totalitarian

state—we who believe in the superiority of democracy to autocracy or oligarchy, of free enterprise to state regimentation, must translate that belief into action that will continue to justify it. We cannot rely on the great achievements of the past; here and now, and tomorrow, we must go on achieving.

If the Axis powers gain the rule of the Eastern hemisphere and the oceans that wash our continent, we have evidence of the sort of world order to which we shall have to conform. We are engaged in an all-out effort to destroy that menace. The British people and their allies are heroically holding the line across the seas. God grant that our aid may not be too little or too late! But on this side we are throwing into the balance, for their defense and ours, a free productive energy unmatched in the world. This, I am confident, will outweigh any force that can be brought to bear by the Axis powers and their enslaved peoples.

Meanwhile, how may we best remove the doubts of our own people as to the worth of the free institutions we are defending, promote the unity of purpose that is essential to the success of any national undertaking, and make sure that we do not drift away, even if not forced away, from the goals that were set for us by our forefathers and that we have long cherished?

This group of engineers represents a broad cross section of our economic life. It includes men of varied activities and responsibilities. The interests of producers, middlemen, and consumers are all well represented; private enterprises, public enterprises, government supervisory agencies. Some are engaged mainly in research; others in operation; others in regulation. Investors, executives, wageworkers, customers—you combine or must take into account all those interests.

You have your individual concerns. But all of us, I suspect, are now taking an increasing interest in the larger, insistent problem of the relation of freedom of enterprise to the changing conditions of modern life; in saving democracy as we of the English-speaking world understand it, in applying its principles practically to our economic activities, in making it work better for the common welfare.

SOCIAL PROGRESS AND SOCIAL ADJUSTMENT

Human society was largely static, as far as the lot of the masses of the people was concerned, until a short time ago. It is so short a time, as history reckons time, that we need go back only a few generations to find common conditions of life not radically different from what had prevailed for almost countless generations.

Indeed the great-grandfathers of some of us, even in well-settled parts of America, had less efficient means of transportation than the Romans of the first century; the horses were no faster, the roads were even worse. Washington could not send a message as fast as could a Babylonian ruler 3,000 years before. The well-to-do American or European of the 18th century had really few conveniences or luxuries that were denied Solomon. The common man had then made little advance in his way of life.

The Industrial Revolution, the Machine Age—call it what you will—which got under way in England in the 18th century, developed fast in America after the United States had won its independence. It had a parallel development on both sides of the invisible border between Canada and the United States. It accelerated the transformation of a static into a dynamic society; it opened a wide road for human progress and of opportunity for all mankind.

With the Industrial Revolution came the growth of real democracy. They were closely interrelated. The engineers were freed by the rise of the mercantile class to work toward the better use of nature's resources for the improvement of industry. Their achievements increased the opportunities of artisans for education, self-support, and social mobility. In America, where social classes were not recognized, government of the people by and for themselves grew from a theory into a reality. It spread to other lands. We foresaw a democratic world.

But the ingenuity of the engineers and the enterprise of the entrepreneurs had wrought economic changes that ran ahead of social arrangements. The changes in the technological aspects of life in the 19th century probably amounted to as much as all previous changes put together since the dawn of civilization. The adaptation of our preindustrial traditions, our preindustrial institutions, to an industrial age has no doubt lagged. Even a free people accepts with more eagerness improvements in its material equipment than adjustments in its social traditions and institutions. Nor did industry, busily expanding, take sufficient account of the social problems of its own making, growing out of that expansion.

DEVELOPMENT OF SOCIAL CONTROLS

The earliest records of community life show that some kind of social control of the economic activities of men and women was exercised. Primitive tribal life could not be maintained in anarchy, and arbitrary controls were the rule, enforced by councils or chiefs or other authority.

In the earlier civilizations that brought men together into large communities, in some cases into nations, there came more division of labor, greater diversity of occupations; but strict regulation by some central authority prevailed, as the Code of Hammurabi and the Egyptian inscriptions, 4,000 to 5,000 years old, reveal. That continued, among nearly all peoples, down to modern times. Individual freedom was lightly regarded, and the ant-hill prototype of society was followed, as far as the lives of most men and women were concerned.

The slow emergence of the idea of individual freedom, that organized society is only a means to the end of serving man the individual, tended to relax social controls of human activities. This very release of individual initiative has so changed the conditions of life, has so increased the interrelations of our activities, that we have to reinterpret freedom in each generation if we are to avoid anarchy on the one hand and loss of freedom on the other.

We now have several types of social control in the economic field. There is the powerful control by *public opinion*, which operates not only through government but also through other channels in a free society. Industry is largely competitive. Producers of similar products com-

pete for public favor, in the price and quality and accessibility of goods they produce. Producers of quite different products compete likewise for a share of the consumer's dollar. The consumer chooses, within broad limits, how to use his purchasing power, and the producer may influence, but cannot dictate, that choice. Public opinion also demands of industry the exercise of social responsibility in relations within industry and in relations to community, state, and nation, and can bring strong pressure to bear in that demand, which neither management nor labor in industry can safely disregard. It is reflected in folkways, in informal standards of conduct, and in the underlying "common law" which still persists behind constitutions and statutes.

Then there are *legislative* controls. Statutes enacted by Congress, state legislatures, and local councils, in accordance with basic constitutions and charters, have come to cover all general aspects, and indeed countless special problems, of our economic life. Taxation is a legislative control increasingly used. The motives of legislative controls may be the pressure of public opinion, or of special-interest groups, pursuit of party advantage, or the personal prejudices or ambitions of legislators; but in the long run the motive of remedy of some abuse or injustice or of other service to the public welfare is perhaps predominant in important legislation. The multiplication of statutes in the economic field, however, whether general laws to be applied to diverse situations and problems or special laws relating to specialized and technical matters, tends more and more to confuse our economic relationships and retard our economic progress. Legislators cannot be expected to be informed regarding all the problems of industry and commerce, nor are their advisers necessarily competent and disinterested.

Again there are *administrative* controls, derived from legislation more or less general, which have loomed larger on the economic stage. Regulatory boards, bureaus, and commissions are set up to carry out in detail the purposes of regulatory legislation. They may combine investigative, legislative, executive, and judicial duties. The competence of a single commission to regulate the policies and practices to be found throughout a vast and diverse field of industry is justly questioned. The extent of regulation may unnecessarily impair or destroy the initiative and responsibility of experienced managements. Over-regulation stagnates production, discourages adventure, checks advance.

On the other hand, government agencies, whether set up for administration or research or other public purpose, may be factors of progress. If they serve to avert unintelligent legislation, and avoid arbitrary decrees themselves, if in consultation with all groups concerned they seek the facts about any problem in controversy and through them a real solution that will represent a consensus, that is a contribution increasingly important in the complex of problems industry has to face.

The co-operation of the United States Bureau of Standards with the work of the American Standards Association illustrates admirably how government may aid in self-regulation in industry and how industry may provide its own social controls with the full sanction, but not arbitrary dictation, of government. The patient and effective work of the councils of that association, including manufacturers, engineers, labor representatives, and representatives of consumers and government, has set a pattern of democratic solution of economic problems.

In a free society, voluntary social control must be exercised if that society is to keep its freedom. The intervention of government comes normally and inevitably when any economic group fails to take adequate constructive action about problems to which its operations give rise. That intervention may be unintelligent and arbitrary, however well intended. It is not likely to serve its purpose if the experience and viewpoints of all groups concerned are not enlisted for the solution of the problems involved. Industry itself ought to take the lead in solving problems of its own creation. Private enterprise cannot survive under a policy of mere negation; it must take hold of its problems and work out solutions on its own initiative. If government aid is needed, this may then be enlisted before pressure for arbitrary government action becomes irresistible.

Let us not raise false issues, or look backward rather than forward. We must face the requirement of increasing social responsibility on the part of business management, and, whether we like it or not, increasing social supervision and regulation of our economic activities. The question management must ask itself, the choice it must make, is whether, on the one hand, to undertake such self-regulation and self-control, not only in individual economic units but also through its associations which represent large sectors of business, in co-operation with government; or, on the other hand, to suffer the increasing imposition of arbitrary controls because some elements in industry too fondly cherish the memory of privileges enjoyed in an age gone by.

The Machine Age, with its transformation of our economic activities, has raised economic problems that must be solved. Shall we go about solving them in a democratic way, with determination to reach a consensus through persistent and intelligent consultations and with full recognition of the obligations resting on public authority to render any needed co-operation? Or shall we admit the failure of democracy, and resign ourselves, with vain protests, to the exercise of dictatorial power by whatever groups a majority may invest with political authority?

INDUSTRY'S SOCIAL RESPONSIBILITY

I would not imply that industrial executives, with the host of engineers engaged in industry in various capacities, lack a sense of social responsibility. Nor is that true of industrial labor. Exceptions may be found all along the line; but certainly all our economic groups have become more socially minded, have acquired increasing vision of mutuality of interests, in the stresses and strains of recent years.

Management recognizes its responsibility to investors for the security of their investment and a return commensurate with the risk involved. A job-creating public-serving business can be maintained only as productive

assets are protected and earnings are available for research and development, for improvement of products and processes, for meeting market requirements. And normal incentives for the flow of investment into industry, for the use of capital in adventurous ways, are necessary to economic progress. Both management and labor have obligations to the investors whose capital they use in the operation of every enterprise.

But management recognizes also its responsibility to labor—I should say to *other* labor, for surely all employees in an industry, whatever their respective duties, are working together with a basic community of interest. Labor is the prime factor in the operation of any industry, and to a large extent is the source, the training ground, of management at its various levels. The right of employees to bargain collectively regarding wages, hours, and labor conditions, if they freely choose to do so, through representatives of their own choice, is unquestionable. If they choose not to join a particular labor organization, because relations of mutual understanding and confidence between labor and management have been established otherwise, that too should be their privilege. There is no one formula of co-operation for all interests in all enterprises; but some basis of voluntary co-operation is necessary where there are association of effort and division of functions.

To the consumer and to the public generally, industry recognizes its responsibility. The consumer, in the last analysis, determines profits, wages, even the continuance of any industry. Management must adjust costs and efficiency of production and distribution to market requirements, and labor must co-operate to the same end. When either management or labor in any enterprise fails to recognize not only the proper interest of all parties actively engaged in it, but also the needs of the consumer, the broader concern of the public at large, and the authority of government, it must bear eventually the consequences of such neglect. Nor is merely passive recognition enough; there must be active, constructive exercise of responsibility, both in individual enterprises and in associated effort throughout each field of industry.

SUGGESTIONS FOR A PROGRAM

With a growing recognition by industry of its social responsibilities, and the need of a more active and concerted exercise of them, it seems to me that in meetings of industrial groups and through committees in which industrial interests are represented, earnest attention should be given to the really major problems of our American economic life—for the purpose not merely of drafting reports but rather of planning co-operative action that will advance us along the road we want to travel.

The National Association of Manufacturers has nearly 1,000 of its 8,000 members working on committees attacking some of these problems and is sponsoring conferences with other occupational groups in a search for clearer mutual understanding. This activity is leading in the direction I have indicated.

I would not venture to draw up a list of all the important problems confronting industry, and the American people, or to appraise their relative importance. Yet I think we may agree that we must find nearer approaches than we have yet found for ten problems that I wish to mention:

1. The "terrible urgency" of our National Defense Program is felt more strongly and more widely day by day. We must concentrate more effort, greater unity of purpose, better organization of our productive resources on doing this job. If we do not give more aid to those now fighting for the defense of the kind of civilization we want to live in—more and more aid now—we shall have to plan for a very different and less inviting way of life.

2. Since this threat of a new world order dictated by powers hostile to our civilization is being faced with increased determination we may expect to check it. Therefore we must begin now to plan for the full use of the productive energies that will sooner or later be released from defense activities. How may we turn them to meet peace-time needs? We know there are accumulated wants of our people that have not been met. We have had the resources with which to meet them but have failed to get together to plan practically ways and means of doing it. The needs will continue to accumulate during this defense emergency. When it is past shall we be ready to provide more and better housing for millions of ill-housed families, more consumer goods at lower prices, needed public works? Not unless we make plans beforehand.

3. We have made great progress in production—in agriculture, manufacturing, mining, and other fields. Has our increased efficiency and economy in production been reflected as far as possible in prices to consumers? Have our achievements in distribution kept pace with our productive achievements? I believe not. Surveys of the relation of production costs to ultimate market prices of many kinds of goods indicate much yet to be done toward low-cost distribution.

4. Agriculture is certainly not in a state of health. It is on sick relief. It should not require enormous government subsidies year after year, seemingly without end. Industry takes part in agriculture. It provides the machines and tools, the fertilizers, and other equipment for crop production; and most agricultural products must be processed by industry, must pass through mill or factory, on their way to the ultimate consumers. Cannot the organizing and engineering skill available to industry give even more help than it has given to restore agriculture to a basis of self-support?

5. Our natural resources are being more carefully conserved than they once were, for proper use without extravagant waste. Private industry and public agencies have co-operated to this end. But millions of tons of soil are still being washed annually into the sea; valuable mineral resources are not being economically used; and every year we are visited by vast forest fires. We can do something about these matters if we will.

6. On industrial research our industries are spending some hundreds of millions of dollars a year, seeking new and improved processes and products. Government agencies and educational institutions also are pursuing many kinds of research. All this has contributed enormously to our economic progress; but we are told that we have only begun to explore the frontiers, that what we know is but a fringe of the probably knowable unknown. A surge of new things will be needed after the war to keep the wheels of industry turning at an unrelaxed tempo.

7. Invention alone does not put new processes and products into use, or make new things commercially valuable. Between a potentially useful invention and its actual use may intervene years of experimentation and development, careful exploration of markets, a large expenditure of venture capital. Out of a multitude of costly failures come some successes—new industries or new enterprises by existing industries, which make for economic progress. In our provisions for regulation of enterprise, therefore, in our tax system, in our industrial operations, every practicable encouragement must be extended to economic adventure.

8. For some years we have been experiencing more or less turmoil

in employer–employee relations. Perhaps these are the birth-throes of an era of better mutual understanding. In many industries, not only where employees have belonged to national labor unions but also where they had independent unions or no unions at all, satisfactory relations have been maintained for a long period of years—indeed for a generation or more. Surely the separation of labor and management into armed camps, policed by government to maintain a truce with a degree of neutrality sometimes questionable, is not a permanent substitute for relations of mutual understanding, with arrangements for internal adjustment of differences, among persons engaged in a common enterprise. The well-ordered household normally needs no policing.

9. Few would now question that there must be some insurance of workers against sickness, old age, and unemployment. In many industries such provision has long prevailed. Society has assumed a certain measure of responsibility in this regard, and this is likely to be extended. Industry, however, should have full credit for what it undertakes whereby the burden on the rest of society is lightened. And social-security measures should be so adjusted and administered as not to remove or impair incentives to individual thrift and forethought, for individual opportunity to earn security is a driving force for enlargement of the common welfare.

10. In a dynamic, progressive society, under democratic institutions, no hard-and-fast line can be drawn between the areas of government action and voluntary co-operation, or between private and public enterprises. It should be our aim, however, in order to preserve the incentives and benefits of free enterprise, in order to avoid a drift into regimentation of individual activities, to make private enterprise as far as possible self-regulating and to develop voluntary controls wherever controls are needed. Freedom must keep reshaping itself as new issues of life require new understanding and new efforts of will. We who believe that the democratic way, rather than the iron way of compulsion, is the true way to a more abundant life for all the people must show our faith by our works.

THE DEMOCRATIC WAY OF CHANGE

We all, being human, might prefer to pursue our accustomed ways of life without being burdened with responsibilities, or pressed to make choices, outside the range of our individual interests. As to national problems, we are prone to say, let others wrestle with them. Perhaps they will solve themselves; or government will take care of them; or they may be left to those who come after us.

Unfortunately for our peace of mind, we of this generation face grave social, economic, and political problems that involve us all. Our forefathers who set up free institutions on this continent, who transformed these colonies into two great nations, who took them through the perils of their infancy, succeeded because they were willing to sacrifice their personal comfort, their private interests, to the common welfare. We who are faced with an even greater common danger can do no less.

If men and women of well-trained and disciplined minds, with experience in weighing theories and facts, in looking from the known into the unknown, do not share the responsibility for choosing the action our nation should take, action which would inevitably determine the direction in which we go, then indeed they will deserve—yes, they will need—the uncompromising command of an arbitrary dictator. If you highly trained, greatly privileged engineers neglect to look up from your slide rules and electrometers, your computations of unit costs and kilowatt-hours, then surely will you come under the domination of masters who knew not Faraday or Edison or Steinmetz. Let us not for a moment forget that our world, drifting under threatening skies and on troubled waters, needs our help—the help of each one of us.

After all, the job that faces the people of both Canada and the United States today is, broadly speaking, an engineering job—engineering National Defense, first and foremost; but at the same time engineering the course of a democratic society. There is at stake the heritage of freedom that has given wide range to the engineering profession and made possible its great achievements. And this society we are defending, this society which engineers have been transforming, is so much their creation that they have more than ordinary responsibility for its future.

The plant of English liberty, growing precariously but deeply rooted in the homeland, fostered by the teachings of the Bible as to the dignity of human personality, was brought to this continent by our forefathers, who gave it rootage in American soil. They declared, in words that rang around the world, the inalienable right of all men to life, liberty, and the pursuit of happiness. They set up the ideal of equality—equal opportunity for all persons to be what they have it in them to be. This freedom, this equality, has been the goal that men and women have cherished here—never lost sight of in the vast change from an agricultural to an industrial economy. Indeed we have not the least intention to give it up for the ancient and ever recurring doctrines of racial dominance, of a glorified state, of an arbitrarily stratified society.

We must not assume, however, that people will long endure the prevalence of poverty in the midst of plenty, inability to distribute widely the amazing achievements of the Machine Age, extensive denial of opportunity through conditions of human creation, or a degree of insecurity for large groups of our people that is surely unnecessary in this modern world. In such circumstances masses of men may be easily led into sacrificing a freedom which they find faltering for a promised security which is dangled before their troubled eyes. Communism, Nazism, Fascism, and other patterns which promise social order and social certainty under arbitrary rule arise not only where democracy has never been tried, but also where it has been found temporarily inadequate to satisfy human aspirations.

"As a man thinketh in his *heart*, so is he." Individual freedom involves individual responsibility. Each generation must earn again, by hard work, devotion to duty, loyal co-operation, productive achievement—yes, sometimes by great sacrifices—its right to be free. Each generation must demonstrate that in free association it can best serve the common good. To exercise that responsibility intelligently, we must feel it deeply in our hearts.

This is no time to dally at the crossroads. Our generation needs a moral and spiritual rebirth to galvanize it into effective action. Perhaps we are undergoing such a rebirth now. I pray that we are. For too long have we been diverted by our separate interests; too long have we failed to realize our increasing interdependence; too little have we taken advantage of our habit of association to develop a common responsibility for making our increasingly complex economic system work. We can read-

ily agree that our economic and social problems will be solved better by free men co-operating with enlightened self-interest than by the arbitrary rulers of any totalitarian state. But we must have the will, a patient but persistent determination, to solve them rapidly and progressively, if we are to prove the superiority of our free way of life.

Our emotions have been stirred, too slowly perhaps, but now deeply, by a threat of encirclement by hostile force. We are working together with might and main to destroy that threat. The energy and resourcefulness of a free people are being demonstrated by miracles of production, wrought not under coercion but in voluntary patriotic effort. We are defending our right to be free.

This same energy and resourcefulness can be carried over into the achievement of our democratic goals. Our hearts and minds are the makers of our human environment, our social institutions. With a strengthened will to understand, with awakened imagination, with broadened sympathies, and now with enthusiasm for action, we can—we must—make this democracy we share in the United States and Canada work as an ever more efficient instrument for the common welfare.

Industry, keeping its freedom and using it with constructive effort and social vision, can make America more than ever a land of opportunity—where all people, pursuing occupations of their own free choice, respecting one another's liberties, recognizing their social responsibilities, may exercise their basic right to be what they have it in them to be.

ECPD Should Look Ahead

A Report to the Boards of the Constituent Bodies by the Chairman of the Council

ROBERT E. DOHERTY
FELLOW AIEE

THE engineering profession faces a great challenge and opportunity. It faces the imperative challenge of the unstable new world it has helped to create, and the opportunity to take a hand in stabilizing that world. But if it plans to meet this clear obligation and assume such a role in the life of the country, it should look ahead, measuring the implied responsibilities alongside its capacities for discharging them. Doing this, it would find one fundamental deficiency to be in the capacity for joint action, and another in the character and extent of the engineer's preparation. It is my conviction that these deficiencies are vital and that concerted thought must be given to their correction; otherwise the profession will probably receive and justly deserve the unhappy distinction of having let its next generation down and failed in its national mission.

Irrespective of the extremities of individual opinions about it, Engineers' Council for Professional Development admittedly occupies a position of strategic potentialities in the very broad field of engineering endeavor. Because of the magnitude and the magnificence of its accomplishment in the surveying and accrediting of engineering curricula throughout the United States, ECPD is all too widely thought of as being primarily an accrediting agency. Quite to the contrary, as Doctor Doherty here points out, ECPD provides a channel for the effective coordination of engineering efforts in many directions of public as well as professional significance. AIEE President Sorensen also comments on this topic in his message to the Institute's membership that appears elsewhere in this issue.

Most engineers now recognize, I think, that their profession does have a heavy responsibility in the accomplishment of national stability, but they evidently do not realize that the profession is not yet fully prepared for that responsibility. I urge that it promptly address itself to the task of becoming better prepared, and I submit that there are definite ways in which ECPD should contribute to that task. At the same time, I realize that this contribution cannot be effectively made until the constituent groups reach a clearer understanding and persuasion than they now have as to ECPD's purposes and potential usefulness.

CAPACITY FOR JOINT ACTION

I have mentioned capacity for joint action. The constituent bodies have of course demonstrated that they can co-operate. The formation of ECPD itself is evidence. On the other hand, there is also convincing evidence that professional co-operation has been impracticable. The termination of the American Engineering Council is an instance. The point seems to be that the

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Report by the chairman to the boards of directors of the constituent bodies of Engineers' Council for Professional Development; published at the direction of the AIEE board of directors for the information of the Institute's membership.

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groups co-operate when it is clearly worth while to them individually, and they don't if it isn't.

The question can reasonably be pressed, I think, whether this is now a sufficiently comprehensive attitude. Perhaps it was in an earlier period. Today, however, when problems of the engineering profession as a whole are crying for solution, when on all sides of national life extravagant insistence upon self-sufficient independence is creating forces that tend to disrupt America, engineers must not, I urge, stand by in an indifferent isolation. They have responsibility; whether they would be or not, they are inevitably involved in both general professional and national interests, as well as in the interests of their own particular group. Clearly they should promote the solidarity of the profession so that it may be in position to deal effectively with its own general problems, but especially so that it may take a more vigorous and constructive interest in the common cause of preserving a democratic future for the United States.

Constructive co-operation is at the heart of democratic life, for democracy, if I understand it, is not merely an aggregation of groups in several realms such as the political, industrial, professional. Rather it is a *system* in which these parts are *organically* related to the whole, and in so far as such a relationship does not exist, the basis for national stability does not exist. This is the primary reason why the groups of the engineering profession should cultivate the capacity for co-operation.

DEFICIENCY IN PROFESSIONAL TRAINING

The second deficiency I have mentioned is in the character and extent of professional training. To promote the professional status of engineers is to promote the effectiveness of the profession. This means better selection of engineering students, more appropriate collegiate training, increased opportunity and incentive for the engineer to continue his education after graduation, and fuller recognition of professional achievement. The full accomplishment of such a program of professional development certainly requires co-operative effort.

There are undoubtedly other fruits of professional co-operation and other ways of co-operating, but I have outlined a way in which the profession can go ahead. The purposes involved are precisely those of ECPD.

Thus what I am urging is that the constituent organizations of the Council take a greater democratic hand in the affairs of this conference body which, with wisdom and vision, they set up about eight years ago. But I know that before greater professional interest is taken in the present work and the possible further usefulness of the ECPD in the future, the members of the constituent bodies must understand much better than they do now just what ECPD is. Some think that it is merely an accrediting agency for engineering curricula; others are aware that it has additional functions, but feel that it has accomplished little except in the field of accrediting; a great many fear that it is ambitious to become a superbody which may try to usurp powers of the constituent societies; and there are, of course, those who do not know or care what it is all about. Then there may be others I have not heard from. So there should be an educational campaign by the several engineering groups to acquaint their memberships with the purposes and work of the Council.

WHAT ECPD IS AND AIMS TO DO

ECPD is what its charter says it is. This charter is a great document of engineering statesmanship that clearly points the democratic way toward the further development of the solidarity and prestige of the profession. It says, "The ECPD is a conference of engineering bodies organized to enhance the professional status of the engineer through the co-operative support of those national organizations directly representing the professional, technical, educational, and legislative phases of an engineer's life." To this end it aims to "co-ordinate and promote efforts and aspirations directed toward higher professional standards of education and practice, greater solidarity of the profession, and greater effectiveness in dealing with technical, social, and economic problems".

Thus ECPD is immensely more than an accrediting agency. True, as such an agency it has been eminently successful in doing an extremely difficult job that might, in less able hands, have ended in confusion. In comparing this with other Council projects, however, one should remember that whereas the completion of an accredited list of curricula is the kind of assignment that can be carried out in a few years, most of the purposes involved in other projects are of a kind that cannot be achieved promptly; they look to the long run and require continuing negotiation, study, and research. Hence the current results of the other projects, however important they may actually be, do not appear spectacular. But this fact should not be misinterpreted. These projects conceivably may be in the long run even more important to the profession than accrediting.

In the approach toward the goals of ECPD, the value of new sources of counsel and support is obvious. A significant advance was made last October when the Engineering Institute of Canada was welcomed into the Council as a constituent member. This new expression of common interests with Canadian engineers will afford a liaison which will assure the fullest development of those interests in both Canada and the United States as they relate to the purposes of ECPD. The assurances that I have from the Institute regarding the benefits to the engineering profession in Canada from the work of the Council are very gratifying, and the Council has profited by the presence of its new members.

A final important fact should be emphasized: With the American Engineering Council now defunct, ECPD is the only body that is in position, by reason of direct representation of professional, technical, educational, and legislative interests of the engineer's life, to deal effectively with the broad problem of professional development. It has already taken over from AEC, for instance, the functions of that Council's committee on professional ethics. The member groups, however, will bear in mind the fact that ECPD is an advisory service organization, wholly responsive and responsible to its constituent bodies; and

the Council must be cautious to confine itself to matters strictly within the scope of its charter and to avoid the danger of spreading itself too thin. But the fact remains that if co-operative progress is to be made by the engineering organizations, ECPD is now the only central medium through which that progress can be made.

ECPD Membership and Activities

A complete understanding of the Engineers' Council for Professional Development must include a knowledge of its constituency as well as the work in which it is engaged. Here emphasis should again be placed on the fact that the Council has functions of advice and recommendation only and does not administer any project unless it is definitely approved by a majority of the constituent groups.

The constituent bodies include the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Chemical Engineers, the Society for the Promotion of Engineering Education, the National Council of State Boards of Engineering Examiners, and the Engineering Institute of Canada.

The work of the Council is indicated by the activities of five principal committees. Concerning these activities I append brief reports for which I am indebted to the respective committee chairmen.

STUDENT SELECTION AND GUIDANCE

Recognizing the importance of providing for interested young men information concerning the mental, physical, and personal requirements for a reasonable future in the engineering profession, the committee on student selection and guidance is organizing committees of engineers to meet with those high-school boys who have made inquiries concerning the study of engineering. Probably 8,000 boys attended such meetings last year. In carrying on this work the committee has received valuable support from the secretaries of the national engineering societies holding membership in ECPD and from the local sections or committees of these societies. Local and state engineering societies also have aided. Moreover, the public schools, except in one city, have welcomed the help of engineers in giving information concerning the education and work of men in our profession. Gratifying reports have been received concerning the helpfulness to the high-school boy of such personal contact with a practicing engineer.

Linked with the problem of providing adequate guidance to prospective students is that of making possible the selection of better engineering talent. The committee is studying means of measuring more effectively scholastic proficiency and personal fitness for collegiate and professional training. In order that entrance into the study of engineering may be confined to those likely to succeed in it and that as a result withdrawals may be reduced, the committee is urging higher standards of admission to engineering schools.

To succeed the pamphlet "Engineering: a Career, a Culture", published by the Engineering Foundation in an edition which is now nearly exhausted, the committee has prepared for publication another entitled "Engineering as a Career". The usefulness to ECPD of such a publication on guidance is great.

ENGINEERING SCHOOLS

The committee on engineering schools, for the first time in the history of our profession, has appraised in an unbiased manner the programs of study of engineering schools, and has prevented a multiplicity of accrediting agencies in the field of engineering education by preparing a list of 542 undergraduate engineering curricula in 125 institutions; 164 curricula were inspected but not accredited, and action on 3 curricula is pending. Though the major portion of the program was completed by October 1939, the activity of the committee during the past year has included the reappraisal of 70 curricula not previously accredited and the inspection of 32 curricula not on the accredited list of October 1939.

The basis for accrediting has been a sound educational program, and inspecting committees were cautioned against undue standardization or forced regimentation of engineering education. Quantitative criteria were subordinated to qualitative factors as a measure of the soundness of a program of study.

The visits of inspection by ECPD committees since 1935 and the friendly advice given to engineering schools, when requested, have resulted in higher entrance requirements, better curricula, more adequate facilities in building and equipment, and improved as well as enlarged engineering-teaching staffs.

An analysis of the data gathered by the committee on engineering schools and a report thereon were made by Professor D. C. Jackson at the instance of the committee with the financial support of the Carnegie Foundation for the Advancement of Teaching and published in 1939 as a pamphlet entitled "Present Status and Trends of Engineering Education in the United States". A copy was sent to the office of the president of each institution supporting an engineering school on the accredited list, to each dean of an engineering school on the accredited list, and to the libraries of such schools. Other copies were made available through the headquarters of ECPD.

PROFESSIONAL TRAINING

Professional training is part of the continuing processes of education that are but barely begun in the engineering schools. In the first few years after graduation, the young engineer finds his most serious challenge. If he is to continue to advance in the profession, he must do more than acquire the technique and practices of his immediate job. His future will often depend as much on the knowledge and experience he gains through contacts with fellow engineers, through working with them to broaden his understanding of the engineer's position and responsibility in society.

To aid junior engineers in this critical phase of their development is the function of the ECPD committee on

professional training. Working with the local sections of the constituent societies, it has encouraged the organization of many junior engineering groups throughout the country. Most of these have for their chief objective improvement in the professional status of their members through study courses, lectures and discussions, plant visits, and inspection trips. Self-analysis questionnaires and suggested reading lists of both engineering and non-technical literature have been prepared by the ECPD committee for the use of these junior groups. In some communities the committee has co-operated with the engineering schools in organizing and publicizing their extension courses. Now that the National Defense Program has stimulated many companies to set up training courses within their own plants, the committee is finding a still greater opportunity to help young engineers take root and grow in the profession.

PROFESSIONAL RECOGNITION

Professional recognition is a normal goal following the attainment of an engineering diploma and professional training in the school of experience. The committee on professional recognition is concerned with "methods whereby those engineers who have met suitable standards may receive corresponding professional recognition". The principal agencies according recognition are engineering societies (independent and autonomous, and differing in their requirements for membership) and state engineering registration boards, operating under different laws in seven-eighths of the states. ECPD has set up as a "suitable standard" certain minimum qualifications for an engineer—including education and capability developed in practice—which are generally accepted and afford a basis for common requirements for society membership and legal registration.

Professional recognition—the goal of education and experience—implies entrance into the engineering *profession*, and the young engineer should understand just what his profession is and what are its privileges, opportunities, and responsibilities. But just what is it? It is not a single organization or a unified group. Its development has come principally through many societies devoted primarily to technical advance in their respective fields. This development, while fruitful in technical progress, has not promoted professional solidarity. It is true that recently legal registration by the states has created a new grouping on the basis of competency, but though the 70,000 registered engineers about equal the total membership of the older societies, a majority of each group does not belong to the other.

In its recent annual report the committee urges that our societies make "a study of the engineering profession including its present status and development" and seriously consider whether their "profession can adequately meet its obligations and opportunities as an aggregation of individual groups, loosely linked by numerous common agencies". It also urges that our societies encourage their student groups to become "interested in a study of engineering as a profession, including its present status and its development; also the field of professional ethics". The ideas and ideals implanted annually in 10,000 engineering graduates leading them to distinguish engineering as a profession from engineering as a technical occupation, may give the coming generation a better profession than we have known.

The committee is planning to take up directly with the proper officers of the several societies the carrying out of the general projects above mentioned.

Summarizing, the general objective of the committee is to develop a proper understanding of what constitutes the professional status of the engineer as a basis for professional recognition and to help engineering students to an appreciation of professional attitudes and conduct.

PRINCIPLES OF PROFESSIONAL ETHICS

This committee was originally sponsored by the American Engineering Council, and upon the discontinuance of that body the sponsorship was taken over by the ECPD, additional members having been appointed in order to provide representation for all the constituent societies of the ECPD. Prior to this change in organization, the committee had undertaken a study of existing codes of ethics in the engineering field and had considered the advisability of a universally accepted single code and the form which such a code should take.

Though progress has been slow, as is natural where communication must be carried on mostly by correspondence, there is now being formulated a preliminary draft of a report on a code of ethics for guidance in the engineering profession. This report will contain (1) a preamble briefly stating the origin and the need in intimate life of canons of ethics, (2) a statement of underlying principles, (3) a statement of reasons for excluding from the present code business rules of practice, and (4) a specific code for ethical conduct.

The object of this study is to bring to the attention of prospective and practicing engineers an ethical code, generally adopted, which may stimulate the minds of students and the younger engineers toward ethical thinking and may supply to mature engineers information regarding what their societies expect of their professional conduct.

If such a report, when completed, is approved and recommended by the ECPD, the committee feels that the governing boards of the constituent societies may come to adopt it as their individual and collective expression concerning the field of ethics and that it may gradually be adopted by the local engineering societies, with the result of a very definite contribution to the solidarity of the engineering profession.

The foregoing brief review of the composition, opportunities, and current activities of the ECPD indicates something of the Council's fitness and of its officers' plans for putting into effect the objectives of its charter, as well as something of the progress it has already made. Looking ahead, the Council is justified in the hope that with the active interest and adequate support of the constituent bodies it may serve engineers increasingly in the cause of professional development.

The Old Order Changes but Men Run True to Form

President's address presented at the 1941 AIEE summer convention

ROYAL W. SORENSEN
PRESIDENT AIEE, 1940–41

THE AIEE constitution prescribes a president's address at an annual convention. Two weeks ago, we realized the import of that prescription and cast about for a subject worthy of our members' attention and a few of those precious premium pages in our publications.

Following the usual practice of an engineer, we did a little research and spent a long day reading the addresses of past presidents to see what they had done under like conditions. Have any of the rest of you ever read all the presidents' addresses?

Out of that study, several harvests were gathered. Two of the direct ones were an interesting and satisfying day, and the knowledge that there is no pattern for such an address, beyond the quite frequent use of an opening sentence equivalent to the one I used. Among the indirect harvests was the conception of the subject for our address, "The Old Order Changes, but Men Run True to Form". Both parts of that are borrowed, as are probably, though unintentionally, other things that will be said.

The words of the first part of the title, "The Old Order Changes", were stored in my mind many years ago when I was a boy in school. They are found in Tennyson's "Coming of Arthur" and also "The Passing of Arthur" and read:

"The old order changeth, yielding place to new;
And God fulfills Himself in many ways,
Lest one good custom should corrupt the world."

The second part of the title probably came from the lips of an athletic coach who, disappointed, disgusted, and angry, was trying to account for the reason why a man on his team who could run faster than any other man in the race had been careless and lost the race. Perhaps if we all stopped at this point and spent a quiet hour thinking about all the subject suggests and then discussed our ideas, we would learn some lessons from the subject, but we wouldn't keep quiet and the president must make an address.

The constitution does not state that the contents of the address must be original. Indeed at one time, in the interest of brevity, quality, and timeliness, we felt inclined to read President Lincoln's "Gettysburg Address", and add thereto the words: "Engineers, our inventions, machines, and methods are being used by power-mad, fanatical tyrants of the anti-Christ breed. What must we do to 'break it up'? "

A PRESIDENTIAL SWAN SONG

The prescribed time for the president's annual address is "an annual convention". For many years it has been delivered at the summer convention near the end of his term, perhaps to give opportunity for him to tell the members what he has learned during the year that will benefit the Institute during the following year. Or it may be just a nice way to let him know he is about through receiving all the glories, free banquets, and other emoluments of the position of great honor; provide a time for him to sing his swan song; and ease the way for him as in true democratic fashion he becomes again just one of the 18,000 members. Be that as it may, neither idea is new. Other presidents have commented about both those possibilities. Many of them have given valuable information resulting from their rich experiences as president, and none of those who mentioned the swan song idea have let their addresses really be a swan song, but, rather, they thereafter have increased their service and value to the Institute. As president, one can learn more about the Institute's possibilities than can be known without that experience. Like many who have preceded us, we did not accept the presidency for the honor thereof, but rather to have an added opportunity for service to the profession which has made us what we are. Indeed, may we join with our 1906 president, Schuyler Skaats Wheeler, who in his presidential address entitled "Engineering Honor" quoted from Francis Bacon:

"I hold every man a debtor to his profession; from the which as men of course do seek to receive countenance and profit, so ought they of duty to endeavor themselves by way of amends to be a help and ornament thereto."

We have tried faithfully to help, but cannot claim any great success at being an "ornament thereto".

In that endeavor to help, we have traveled during the time spanned by the conventions at Swampscott and Toronto, some 60,000 miles, or the equivalent of more than twice around the world; made visits to 43 of our 72 Sections, 32 of our 123 colleges having Student Branches; attended two summer conventions, a winter convention, a Pacific Coast convention, two District meetings, three District student conferences, and several joint Section and Student Branch meetings. The annual report of the board of directors contains a record of most of these activities.

Indeed, there is a world of information in that report which Secretary Henline has assembled. If you would know what has been done during the year, read it. Such a report, long as it is, cannot include all the time-consuming incidental activities such for example as the complete rehabilitation of the members' rooms at Institute headquarters, and details of a lot of work of various types in connection with the National Defense program. Taken altogether, the year has been a very successful one for the Institute and the president, to a degree which leaves no

regrets for the large amount of time required for the work. Indeed, we hope some of the things done are marks of permanent progress.

Several presidents have used the word "co-operation" in the titles of their addresses. Others referred frequently in their addresses to that characteristic as an element of all engineering. During the year, we have often observed co-operation to be the very essence of Institute accomplishment. The other technical societies know its value and whenever requested to do so have aided us in many ways. Secretary Henline, Editor Henninger, and all the other members of the employed staff have co-operated with a loyalty and complete accord for which no amount of salary can pay. The board members have functioned as a happy, industrious unit in thought and action—not always in agreement perhaps at the beginning of a discussion on some question, but analytical and unanimous when the time for decisions arrived. All committees and officers have done valiant service. Almost every member requested to render some service, great or small, has responded in a way such as would please you all, could you know of the many requests and responses that have been made. There have been many volunteer suggestions, not all of which could be used, but few indeed were made with any motive other than the welfare of the Institute and the rendering of valuable service to its members. Less than a dozen of all our 18,000 members have presented self-interest problems for solution and most of those were proposed because the individual concerned had in mind some principle of conduct to which he thought the Institute should give attention. Employers of our members have granted time for Institute work and given encouragement and support for its activities. Members' wives and colleagues have made our work their interest and aided us in making the Institute a success whenever given that opportunity. Particularly do we know these things to be true in regard to the California Institute of Technology, our staff of associates, and Mrs. Sorensen. Thus have all interested in the AIEE "run true to form". To all who have been mentioned and to many that time will not permit us to name, we pay tribute for the co-operation rendered in Institute affairs and National Defense work.

AIEE—1884 AND 1941

"The old order changes"—the AIEE was established in 1884, and, hence is the youngest of the four Founder Societies, the other three the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, and The American Society of Mechanical Engineers, being founded, respectively, in 1852, 1871, and 1882. The AIEE, according to the records, was launched rather hurriedly, with its first headquarters at the Franklin Institute, furnished free of charge in order that the electrical engineers of the United States might have "face" in the eyes of guest engineers from across the Atlantic attending the Electrical Exhibition held by the Franklin Institute in Philadelphia in September 1884. Thus our engineering society was founded. The early-day AIEE programs make an interesting study. In those days only a few men were working with electricity and the machinery for its use. They met to discuss their technical problems and present technical papers. Wisely, provision was made for printing those relatively few but epoch-making papers.

Thus the AIEE TRANSACTIONS was born. The early volumes are small, although they contain full accounts of all meetings in detail, even down to remarks made in introducing speakers and in discussing simple matters of business, now considered of too little importance for publication. At the present time, the TRANSACTIONS, because of cost of publication and other factors incidental to the large amount of available material, does not present a complete record of all Institute activities. In fact, one can now survey the complete record for any Institute year only by use of both the TRANSACTIONS and ELECTRICAL ENGINEERING.

Every paper presented in those early days was a technical paper describing some specific bit of work done by an engineer, usually an Institute member. That practice is still followed in our technical sessions, but with this difference—there are now more papers per convention session and the Sections each have a larger meeting attendance than that of former entire conventions or meetings. Also, at present there are practically always several technical sessions meeting simultaneously, rather than only one at a time. Certainly no one would venture in these busy days even to think of having only one session at a time at conventions, because to do so would make the conventions of impossible length.

Furthermore, since there are now so many unique things to be discussed by specialists, it is obvious that any one technical paper is likely to be of particular interest to only relatively few of our many members. Indeed, many of our papers are so specifically technical they can be understood by only a very limited number of members. We are no longer a homogeneous single-interest group of electrical engineers, such as one time constituted the AIEE membership.

SHOULD THE SOCIETIES COMBINE?

The co-operative habit of engineers has been mentioned. That characteristic has become so fixed in the minds of many engineers as to make them think that there should be just one engineering society so engineers may become a power in the political and economic life of the nation. It is high time that engineers should exert more influence upon those activities. There is, however, only meager evidence that the way is through the one-society route. Not all theoretical ideals are practical, as has been well demonstrated by the endeavor during recent years of an idealistic group of men untempered by the rigors of their own hard knocks and private business successes to give every citizen dominated by a powerful single organization a life of abundance, even though the government be the sponsoring organization.

Once there was in civic life just one engineering group, the "civil engineers", known as such in order to distinguish engineers in civic life from military engineers. Admittedly a unified engineering society of more than 100,000 members working together could accomplish some of the things we would like to see done. Is it, however, equally certain

that the total accomplishments of the several smaller groups would have been equalled had all engineers tried to function through a single society? Probably our electrical engineering activities are further advanced than they would have been if the AIEE had developed as a branch of the ASCE.

The Institute of Radio Engineers and the Illuminating Engineering Society are organizations carrying on work which might well be a part of the activities of AIEE and often the wish is expressed that all the work embraced in the activities of those two societies might be done as a part of our program. Are we quite certain that the things they have done could have been done any better as a part of our large program? Indeed, it is quite probable that some of these things would have been done less effectively under such conditions. Moreover, have we, merely because there are several engineering societies, any less professional recognition than was accorded to engineers when there were only military engineers and civil engineers, or than would be ours if we were combined in one large society? Perhaps the major factors which determine recognition are the trends of the time and our conduct as individuals, rather than our society activities.

The natural trend in every growing enterprise seems for a time to be one of consolidation followed by a period of decentralization. The societies responsible for the professional standards and recognition of engineers to date have skipped the consolidation period, but after all, great nongovernmental consolidation schemes seem to have gone out of style. We trust that consolidation of business as a governmental activity will soon start in that direction. Some of our presidents in their addresses have said, "Engineering is not a profession in the same sense as the legal and medical professions". No doubt those comments were prompted by the fact that, while engineering activities since their beginning have gained steadily in recognition as professional activities, the number of individual relationships between client and consulting engineer during the last decade has been decreasing in favor of increased employment of engineers in large numbers by corporations and governmental agencies. There are many conditions that seem to make engineering a family of professions rather than one single profession. When families are considered, each one seems to have its own unique problems, many of which are not adaptable to other families. Experience regarding family relations teaches that there is always trouble if several families are merged to make one larger family. Indeed, all attempts at joint activities for engineers have not had continued success, notwithstanding all the engineering spirit of co-operation about which we have boasted; for example, the American Engineering Council.

In contrast to a project discontinued, perhaps because its stated objectives were too broad, we have in the Engineers' Council for Professional Development to date a highly successful way of accomplishing co-operatively some things desired by all the participating bodies. By the same token, a continued support for its program promises much and we should all do everything possible to see that such support is given. Indeed, ECPD may become a channel through which the several engineering societies can conduct a number of their activities of common interest, if used for that purpose. Perhaps it may even do some of the things we once hoped to accomplish through the American Engineering Council.

In the early days of the Institute, the president was expected to preside over every meeting, a duty now assumed largely by Section chairmen. The order of those days called for technical papers only, even the president's address. Without a never-ending supply of technical papers, the Institute would be nothing, but in recent years our activities have made desirable a considerable number of Institute papers that deal with the relations of engineering to all the affairs of men. Your president during the Institute year nearing its close has endeavored and is trying at this time to stimulate more participation by our members in the affairs of government, in the hope that a greater use of engineering methods in those affairs will aid in solving some of our world problems.

ENGINEERS AND THE WORLD TODAY

In view of the succession of catastrophes that have happened since we met at Swampscott just a year ago, we may well ask ourselves, "Are we going backward or forward?" From the press and from associates who have lived for a time with the primitive arctic tribes, we learn that the members of those tribes are happy and free from strife, even though their energies are fully occupied by the simple task of maintaining physical existence. At times as we have viewed the misuse of our engineering products, we have almost wished we could go back all the way to such a primitive life. Perhaps such wishes come only when we are tired and for the moment so discouraged with the doings of man that the dull, low-mentality happiness of primitive man seems to transcend the satisfaction we have in the many things that interest us and of which primitive men have no knowledge.

We are horrified beyond measure at the murder and property destruction now going on in the world. Isn't that very reaction something of which to be proud? The inability of men to keep out of war is nothing new, but the ability to be horrified by what war does is quite a recent experience for mankind. The primitive man doesn't conduct a wholesale mechanized murder as great as that which civilized men have under way, but in the presence of murder, primitive man is not horrified. Perhaps he only seems more peaceful, because he is too far down the scale of intelligence to have reached the mass-fighting stage.

We are glad that there are engineers to provide equipment for the life we live. We have faith in engineers, and we agree, even in these awful days, with the several past presidents who in their addresses have declared that engineering is the hope of the world. Engineering is based on measurements. It is not interested only in the making of machines and gadgets. Lord Kelvin, who will be famous as an engineer as long as history is recorded, set up a road sign along the engineers' superhighway when he taught that we know a thing when we can measure it and express it in numbers.

Engineers do not determine the value of a machine on

the basis of the smoothness of its exterior, the color of its paint, or the amount of noise it can make. Before a machine is allowed to leave the factory, every detail of its action is measured by special instruments of precision, each devised for its particular job. Applying the Kelvin standard, measurements have been made and expressed in numbers. The numbers show beyond any doubt how the machine will perform, and determine its right to assume responsibility.

MEASUREMENTS OF LEADERSHIP

Engineers have performed wonderfully in contributing to the many phases of life. They, however, along with the rest of mankind, have failed in the most important task of all—that of teaching men how to behave. That failure may be due altogether to the fact that heretofore there have been no instruments of precision to tell us the nature of the mind of man before he assumes an active part in the affairs of men. Because of lack of such instruments, our leaders all too often have been selected because they please the eye, or because they make a noise pleasing to the ear, particularly since men have become so sensitive to the quality of what appears on the screen and comes over the radio. Men seem to forget that those who operate broadcasting stations and make pictures are expert at filtering out that which is undesirable, even when the director may not be able to correct the fault in the actor.

Engineers must devote more energy and time to the job of finding leaders and telling folks how to measure their candidates. "Men Run True to Form", is a part of our title. The word "men" is used in the sense of including a lot of individuals, each with a rather short span of life during which time he follows very closely a set pattern of action.

Scientists who study the behavior of men tell us that the graphic diagram of a man's sanity or rationalism is often a very irregular curve, showing great strength for some of his characteristics and most deplorable weaknesses for others. It may be just as well that we select our automobiles by centering our attention upon a brilliant paint job or a beautiful horn, because all automobiles today seem to be well made. Unlike automobiles, however, all persons, are not well made and properly balanced. Unless leaders are very carefully chosen we shall continue to have leaders who are mental cripples and try to cover their weaknesses by erratic overemphasis of their prejudices, sometimes with sad and grotesque results. In the extreme this may result, as in the case with Germany, in a powerful people being led by a "neurotic flophouse derelict" who never as an individual succeeded in doing even the simple job of providing a decent living for himself, but who by great emotional oratory can incite his followers to a lust for destroying the whole world, if need be, in order that they may become his slaves. We must not forget, however, that current history tells us the Germans have started five wars in 100 years. Must we let them do it every 20 years? Not if we test and measure.

One small bit of the message which we took to the Sections during the year cited an example of how the electrical engineer assists the biologist by providing him with a set of instruments for measuring the voltages and currents found in the nerves and muscles of animals. Very recently, Doctor Max Mason directed our attention to the success that has been attained in applying a similar technique to the measurement of the mind of man, thus enabling us to have a graph of his rationality without the necessity of observing his conduct over a period of years. We also are finding out that many mentally ill patients whose curves show bad characteristics can be so treated that their rationality curves will improve greatly. This new application of electricity, based on our newest tool, the vacuum tube, may well become the most valuable contribution electrical engineering has made to the well-being of men.

At present, our one big immediate job is the National Defense program, which means "STOP HITLER". In that effort we must back our leaders to the limit, even if the methods in use are not altogether to our liking. Hitler shall be stopped! We hope very soon. When that is done, a program of government of the people, for the people, and by the people will again have a chance.

When all is said and done, we are fighting this war in order that we may have another chance to do what we failed to do at the end of the last war—establish a program whereby nations working together can give all the citizens of the world an even chance at its bounties, regardless of race, color, nationality, or geographic location. To do this, pending a perfection which may not come for centuries, a part of such a program must provide for the discipline of those who won't conduct themselves according to the accepted rules.

Nothing will be gained if we do not choose leaders at all times equal to the able ones we have occasionally elected to office. Also, we must select very carefully our immigrant citizens, making sure they come to us with the idea of abiding by our way of living, which to date has proved the best in the world. We cannot make Americans of men who come only to try and make us over according to their own plans. Every immigrant should be compelled to furnish a record of his rationality test. Above all things, men like Harry Bridges and other noise makers of his pattern should not be selected as leaders to guide the many men who themselves are unwilling to lead in the American way the battle for the rights to which they think that they are entitled.

THE INTELLIGENT VOTER'S TASK

Indeed, we should be very careful in the future that we who think we are intelligent voters be not led astray by appearance and high-sounding phrases in the selection of government officials. We should demand of those who would occupy high offices something more than ideals inspired by the dramatic five-year plan of the Soviet Union; the apparent lack of unemployment brought about by the regimentation of business, labor, and banking in Facist Italy; the restoration of national pride and self-confidence to a beaten people by Kemal, Mussolini, and Hitler; or even the example of England's abandonment of the gold standard. We should demand that the

whole program of what America should do be studied, and that the wild schemes of other countries be not tried on us before they have been used long enough for us to know their results. Who wants an America that follows examples that tend to lead us where Germany, Italy, Russia, and Japan have gone? Russia still has rulers who are true to the form of the czars. The change in name and the type of life that they said they would provide have proved to be only bait to change from one line of tyrants to another. The free schools of which they boasted are gone. We still have ours. No man in Russia, according to recent edicts, can change his job without government order. If he misses work, he is called a criminal and sentenced to go back to the same work at less pay. Italian, German, and Japanese employment programs reached a point where they could be continued only by making war on other nations and when war is over those people will be in a very much worse situation than they were at the close of the last war. The world problems are our business, because we will be dragged down with the rest of the world. We are paying the bills and will continue to have to pay them for years to come. We know that worse than all the destruction of life and property is the backward step in moral, ethical, and religious standards caused by what war teaches. We must work every antidote against that to the limit to make the backward step as short as possible. When these results can be measured, and are measured, perhaps people who are not engineers can also be taught that in war everyone loses.

PROGRESS TO DATE

What are some of the good signs? It has been said that we have reached a stage where we think war is horrible. While the history of man is long, the Christian way under which we have tried to live is only 2,000 years old.

Men have been measuring things, other than a few dimensions and time, only 300 years, for measurements really began with Galileo. Many things now measurable were not measurable until we knew how to use electricity as a servant for work and messenger service. That we have done for only half a century. World-wide instantaneous radio communication, with its vacuum-tube technique, the electron microscope, the studies that have been made with uranium 235 (atomic energy), and the electrical testing of men's minds that has just been mentioned, as well as other applications of electricity, are so new that the methods of doing them are yet unknown by many engineers, to say nothing of laymen.

Some of our members have contributed largely to all these achievements. All of us have done something to keep AIEE in the vanguard of all these affairs and the Institute, in turn, has done much to keep its members informed that none may lag behind the trend of the times.

We are optimistic enough to believe that those who are piloting the affairs of the nation, confused though they may be, will keep the ship of state afloat and, it may be, will navigate so well that even through the storm good progress will be made. The electrical engineers are still ready to measure and provide new measuring instruments. The American Institute of Electrical Engineers will do its part, if its members also become members of civic as well as technical organizations. Coming years will prove that scientific civilization founded on fact and guided by Christian principles cannot be destroyed. The war will end and our job again will be one of trying to teach all our people how to use machinery as well as to make it.

When we get back to that job, we should like to avoid a repetition of some of the wild economic experiments that have been tried during the past decade. Things like a completely gratuitous program of relief and abundant life without work on the part of man were proved to be unsound centuries ago. The Lord had to give up his total-relief program, drive Adam and Eve out of the Garden of Eden, and put them to work, in order that He might have a chance to save their souls. Engineers do not flinch when problems are hard, but they do crave the right to work them through without the dictates of an overlord.

This great American continent has its traditions. Intangible though they are, they have made it the grandest place in which to live regardless of the spot where one may be—Quebec, Boston, New York, New Orleans, San Francisco, Vancouver, or Toronto. It has produced a citizenry of many patterns and differing habits, but it also has produced the "American way of life" founded upon the principle of "live and let live". If that way of life is not diluted too rapidly by the addition of those who do not know what it means, we shall continue in the way of our predecessors to have the glory of what President Charles E. Wilson of the General Electric Company calls an "American free-enterprise system", regardless of the names created by politicians to propagandize election ambitions and of all the blunders made in trying to make those names have meaning. Much of the American way of life is due to engineering achievements and engineering methods.

The literature of the day is very complete, so that "he who runs may read". Indeed there is all the information one needs about where we are and where we should go in two recent articles that I have read: an editorial in the *Saturday Evening Post* of June 14, 1941, and a booklet "Against This Torrent" by Edward Mead Earle.

When this generation of Americans is fully awake, they like those who pioneered before them, will prove that they have what Francis Bacon said is more essential than all else: "The iron of determination in the body politic". When that "iron of determination" gets going we can solve our war and post-war problems.

The engineering method can be such a valuable tool for governing the acts of men in a machine age that it should not be limited to the mere production of machines, but should be applied also as a guide to their use in our everyday problems of human relations. Engineers must be diligent in teaching to all the people the way the engineer solves his problems. There can be no defeat for the English-speaking citizens of the world if they will work for Christian ideals in all political and economic relations and make them practical by using in that work the engineering methods which are based on knowing the truth. For is it not written "The truth shall make you free"?

Applications of High-Voltage Fluorescent Tubing

JULIAN A. McDERMOTT
ASSOCIATE AIEE

Advances in application of high-voltage fluorescent tubing are making it increasingly useful not only as a sole light source but also as a complement to other sources. Presented here is the scheduled conference discussion on the subject given at the AIEE 1941 winter convention, supplementing other scheduled discussions from the technical session and conference on fluorescent lighting which appeared in the June issue.

HIGH-VOLTAGE fluorescent tubing is the logical development of the simple cold-cathode low-pressure discharge tube. Transformers, glass, and wiring methods have not materially changed but the fluorescent coating has been added to the inside walls of the tubing. Advances have been made, however, in the techniques of use, and the inherent characteristics of the light source offer wide possibilities for future exploitation.

CHARACTERISTICS

Electrical. High-voltage tubing is operated with a transformer having constant current characteristics obtained through the use of a magnetic shunt. From 1,500 to 15,000 volts may be used. Tubes are connected in series. Under the proper conditions more than 100 feet of tubing may be connected in series and operated from a single transformer.

Tube currents range from 8 to 250 milliamperes. Devices have been developed and are gradually coming into use that will increase the safety where high voltages and currents are used. These include spark-gap thermal relays which shunt out defective tubes or cut off the current, and magnetic devices operating on the transformer which interrupt the primary circuit instantaneously when an open circuit occurs in the secondary.

Dimming is accomplished by voltage control, either by primary taps or by primary resistance methods. Those tubes employing mercury are best adapted for this purpose because of the lesser tendency toward flickering with lower voltage and current values. There are limits through which certain types of tubes may be dimmed and careful consideration must be given as to electrodes and processing for any particular service.

Tubes may be obtained having wattages of from $1^1/_2$ to 17 watts per foot over-all.

Shape and Size. Tubes having outside diameters of from one-half inch to one inch may be obtained commercially. Lengths generally are limited to 12 feet on account of difficulties in handling and processing. However, it is recognized that longer lengths are desirable, because the electrode losses are considerable and the efficiency of longer tubes would be higher. Tubes may be bent to sharp curves or other irregular shapes.

Color. A wide range of colors is available, including numerous whites, green and blue which result from mercury-vapor discharges with mixed argon- and neon-carrying gases, and salmon, rose, and pink which result from neon-gaseous discharges. Those tubes employing mercury are subject to serious depreciation in cold weather, but a green tube and a white one have been developed which operate at fair efficiency and which do not employ mercury. Properly processed tubing should have no starting difficulty in cold weather and should show no dark spots or discoloration during its life.

Efficiencies and Life. Tubes of this type can be made that will operate for very long periods. Many records are available of installations operating for 16,000 hours or more without the replacement of any sections.

Efficiencies are somewhat difficult to establish because of the great variation among tubes obtained from different sources. A number of manufacturers are merchandising

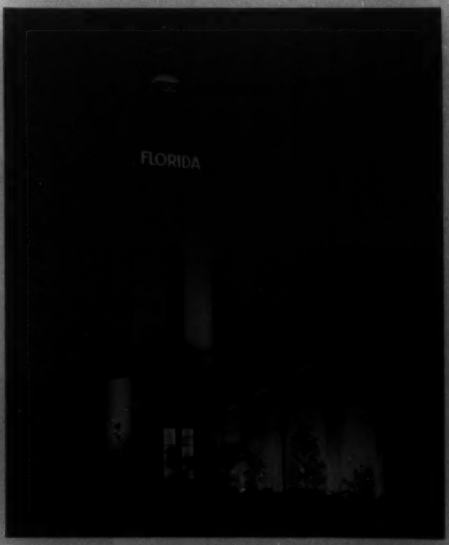

Figure 1. Plastics and high-voltage fluorescent tubing were combined to provide an effective sign for the Florida building at the New York World's Fair

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Figure 2. The use of curved tubes produces interesting and satisfactory decorative fixtures

coated-glass tubing. This is fabricated into sections and processed by thousands of manufacturers who have considerable variation in procedure and in general little engineering control. The result is that the products differ considerably in characteristics.

The tubing used for sign work must be so coated with fluorescent powder that adherence is maintained although sharp bends are made in the glass. This generally is not conducive to obtaining maximum efficiency. The wattage consumed in any section of tubing is the total of the electrode losses plus the column consumption; hence the longer lengths of tubing are most efficient. The size of tubing in greatest use is 15 millimeters in diameter and is employed with transformers rated at 60 milliamperes short-circuited and operating normally at 48 milliamperes. The over-all average wattage of mercury tubing operating under this condition is 7 watts per foot.

Tests on samples 3 feet in length gave the following efficiencies:

	Lumens Per Watt
Warm white	28
Cold white	26
Yellow white	32

Efficiencies were established after 200 hours of operation. At that time the initial drop in intensity had taken place. Samples of many white shades had indicated an additional drop in intensity of 30 to 40 per cent up to 5,000 hours. After this life is obtained the depreciation curves usually flatten out, showing only a small variation. Test samples indicated a total loss of 50 to 60 per cent over 12,000 hours.

It must be repeated again that these are average values for good tubing manufactured essentially for sign purposes, and operated with transformers manufactured for that purpose. Higher efficiencies are available where tubing is manufactured for the specific purpose of illumination, where longer lengths of tubes are used, and where auxiliary equipment designed for this specific purpose is included.

For most illumination calculations the average values mentioned will suffice, but where greater accuracy is essential a study must be made to determine the most desirable values for the length of tubing, gas mixture and pressure, life of electrode material, tube diameter, coating material, and processing.

APPLICATIONS

The more general uses to which high-voltage fluorescent tubes have been put include advertising, illumination, photography, and specialty purposes such as aviation signals and colorimetry.

Advertising. The widest field of use has been for signs where high-voltage tubing has been substituted for red neon, helium-white, and blue and green mercury tubing. The tendency is for this type of tubing to supersede all the previous tubes used for advertising. It is more efficient, has a greater visibility, and is more resistant to the effect of cold weather than the ordinary mercury blues and greens; it is more efficient than the helium type of tube; and many municipalities are giving consideration to prohibiting the use of red neon and green tubing for signs because of interference with traffic signals.

The high light output of this tubing has permitted the wider use of translucencies and plastics to obtain more effective advertising displays. A typical installation was the "Florida" display at the New York World's Fair (figure 1). Four deep blue tubes were arranged behind laminated plastic sheets forming the name. The daytime effect was that of a solid block of letters, so that the architectural features of the building were not impaired. At night the deep blue color offered a striking contrast to the incandescent flood lights. Other such uses include the

Figure 3. Fluorescent tubing is used for ceiling coves and showcase lighting in this haberdashery

Photo courtesy Federal Electric Company

Figure 4. Cove lighting and staircase illumination in this lobby illustrate the flexibility of high-voltage tubing

edge-lighting of letters formed of transparent plastics or glass, and the lighting of silhouette block letters mounted on walls.

Considerable application has been found for these fluorescent tubes in portable signs having interchangeable letters. A high-frequency vacuum-tube oscillator is used instead of the transformer, and the tubes may be operated in multiple. Connections are made to the tubes through metallic plates of suitable capacity mounted in the bases of the letter holders. In this way extreme flexibility is obtained.

Illumination. Fixtures employing high-voltage tubes have begun to appear on the market. Generally these take decorative forms. Bent tubes may be made into an infinite variety of patterns.

In figure 2 the elementary forms of concentric rings are adapted to custom-built fixtures. Numerous installations have been made where the tubes, usually of various colors, are incorporated in fixtures or are mounted on the ceiling to form a decorative pattern. Generally a number of colors is included so that both mercury and neon discharges are obtained. In this way a more complete spectrum range is obtained and the effect of the resultant color on fabrics or food is satisfactory.

The use of combinations of colors to get the most acceptable light for the examination of clothing is shown in figure 3. Three white tubes and one neon gold tube were located around the ceiling cove to provide a high level of general illumination in the sales area. In addition tubes one-half inch in diameter were located along the front edge of the showcases and in vertical bars on the wall cases to provide inconspicuous but effective background illumination.

The use of tubes for a specific illumination problem where space is at a premium is well illustrated in the lobby installation shown in figure 4. Small-diameter tubing illuminates the stair from its position under the hand rails. The cove above is illuminated with a tube shaped to fit the wall curvature. Turnbacks are made in the lengths of tubing so that all shadows from connections are eliminated.

A high-intensity installation is shown in the exposition building (figure 5). Tubes 12 feet in length formed a huge grid on the ceiling and produced 35 foot-candles on the floor. Floor displays are emphasized by incandescent down lights recessed into the ceiling. Tubes operated at 120 milliamperes were installed so that joints between sections were unnoticeable. Where long lengths can be used this type of installation is extremely effective and efficient.

Probably the most effective and exciting uses to which high-voltage tubing has been put are those in which a number of colored tubes are installed in coves for background illumination and incandescent spotlights are used to emphasize objects of special interest. With this medium the designer can at last "paint with light" and the whole feeling of a room can be changed by the snap of a switch. A number of such installations have been made in showrooms, night clubs, and stores, using red, green, blue, and orchid tubes. Usually the tubes are operated at about 3 watts per foot and the cost of operation and replacement is small.

The small-diameter tubes are also useful where projection is desirable and they may be incorporated in optical systems where fluorescent tubes of larger diameter would be ineffective. This method has been used for high-bay factory illumination and for high-cove indirect-lighting systems where Alzak parabolic reflectors were used in the cove.

All the installations mentioned were designed before the revision of the National Electrical Code in November 1940. New regulations were established in that issue of the code whereby the space requirements for electrodes were increased and the installation conditions were in general made more stringent. Although revisions of this code have been discussed, it is effective at this time and the greatest consideration must be given to all designs to assure agreement with its requirements.

Photography. A considerable use has been found for

Figure 5. Architecture and lighting were strikingly co-ordinated in this exposition building illuminated by a huge grid of high-voltage fluorescent tubing

high-voltage fluorescent tubes for enlarging and similar applications in photography. Usually the tubes are aged so that the operation takes place on the flat part of the depreciation curve. The result is that effects can be duplicated accurately at subsequent dates. Blue tubes are used because of their high actinic value. Frequently the units are equipped with dimmers so that the photographic speed is variable.

Specialty Uses. Among the many specialized applications to which high-voltage fluorescent tubes have been adapted are battery-operated aviation and marine signal systems, colorimeters for chemical determination, and units for the production of near-ultraviolet light. The possible specialized uses are evidently many and await only the familiarity of designers with the available features.

TRENDS

The trend of this whole field has been forward. However, the industry in the United States owes a large debt to French research and for the present that is ended. The manufacturing methods generally being followed at present are purely those of a craft. It has not been practicable to introduce machine-production methods, and without these the unit costs are relatively high. Reports from South America and Australia indicate increasing application of this type of equipment, despite wartime conditions. Its place in advertising is secure, but whether widespread advances will continue in other fields of applications depends upon whether the manufacturers can adapt themselves to the conditions facing them and compete against or more fully complement other light sources. Research and development are prime requisites to the solution of this problem and the effect of such efforts is already being felt. Special tubes, processed to give satisfactory effects upon foodstuffs and meat products have been used in refrigerator display cases in considerable quantities. Protective devices that eliminate the dangers of shock and damage inherent in high-voltage systems have been developed and may expand tremendously the applications of this lighting medium.

Low-Voltage Cords Eliminate Shocks

USE of extension cords with special 50-watt transformers to reduce the supply voltage to six volts, by the Public Service Electric and Gas Company of New Jersey, has eliminated the electric-shock hazard in the use of portable hand lamps in damp locations, according to a recent number of *Public Utilities Safety* issued by the National Safety Council, which reported as follows:

"There seems to be a belief among workmen that 110 volts is not harmful and can produce fatal shock only in cases where a man has a weak heart. This is not true. Tests have been conducted which show that when an electrical circuit is completed through a wet contact, any voltage in excess of 12 volts is dangerous.

"Realizing the hazard that existed when work was performed in wet or damp locations that provided a perfect ground for the 110-volt circuit should extension lamps become defective, the electric generation department of the Public Service Electric and Gas Company in 1928 decided to have one of the local manufacturers design and develop a 110- to 32-volt 50-watt transformer. During that year, 1928, all 110-volt extension cords were replaced with the new 32-volt transformer.

"In 1939, however, as a result of further experimentation, this transformer was rebuilt so that its secondary voltage was reduced to 6 volts, which is recognized as an absolutely safe minimum. It is now possible to procure 6-volt lamps with the standard base. Low-voltage transformers of this kind are being used extensively about the property to eliminate the electric shock hazard.

"Cases of electric shock and accidents resulting in falls from shock are recalled which, although in themselves were not serious, indicated the potential hazard that was continuously present. The use of the lower voltage has completely eliminated the hazard, inasmuch as there has not been a single case of electric shock reported since the transformers have been in use."

Institute Activities

The AIEE and the ECPD

A Message From President Sorensen

THE Engineers' Council for Professional Development has completed its eighth year and issued its eighth annual report. Every electrical engineer has an interest in the work of ECPD because the AIEE is one of its eight sponsoring bodies. Each of the eight participating bodies has three representatives. Our representatives are:

JAMES F. FAIRMAN, assistant vice-president, Consolidated Edison Company of New York, Inc., New York, N. Y.

O. W. EBSBACH, dean, Northwestern Technological Institute, Northwestern University, Evanston, Ill.

F. ELLIS JOHNSON, dean of college of engineering, University of Wisconsin, Madison.

The chairman of ECPD for the year 1940–41 is one of our distinguished Fellow members, Doctor Robert E. Doherty, president of Carnegie Institute of Technology, Pittsburgh, Pa., and formerly chief consulting engineer for the General Electric Company. Chairman Doherty has written a special report about the work of ECPD which appears in full elsewhere in this issue. When this report was presented to the AIEE board of directors at its meeting May 23, 1941, the board was of the opinion that every Institute member should have an opportunity to read it. Please do not miss the opportunity. Moreover, the report is so timely and is of such nature that the board considered it advisable for some special comments to be made about it and the work of ECPD; hence this message.

From the beginning, ECPD has had four major objectives, each in charge of a committee. These committees are the committee on engineering schools, the committee on professional recognition, the committee on professional training, and the committee on student selection and guidance. The major task of the committee on engineering schools, namely, the accrediting of engineering curricula, is now well beyond the experimental stage. Many AIEE members, including your president, are participating in that program. As a result of first-hand observations, I wish to pay tribute to those who organized and supervised the work involved in the examination of 791 engineering curricula, 542 or about 70 per cent of which have been accredited. One result of the accrediting program has been the furnishing of a motive for the faculties of engineering colleges to take inventory of their courses of instruction and equipment, particularly in relation to the engineering requirements of industry and the curricula of other colleges, to an extent that would not have been done without some such incentive. These inventories, together with the opportunities afforded for interchange of experiences and suggestions, naturally tend to raise the general quality level of curricula above that which would prevail without some such stimulus.

It has been my privilege to visit recently many of the engineering colleges in the United States and Canada. Some visits were made only to satisfy my desire to know what the colleges are doing. Some were made to fulfill a part of my duty as president of the AIEE, and some were made as inspection trips in connection with the ECPD accrediting program. The opportunity thus given me to make a large number of observations is appreciated, and the only fair thing to do is to pass on some of my observations to members of the Institute.

A number of colleges denied accrediting at the time of a first visit made changes in staff and equipment which gave them accrediting after a later visit. The contrast between the improved accredited curricula and the original nonaccredited curricula is as noticeable as the contrast between day and night. In practically all cases where accrediting was denied at the time of first inspection, the deficiencies found were due largely to the fact that engineering curricula, which at one time had been high grade, had failed to keep pace with engineering developments because those responsible for the conduct of the work in these colleges had not fully realized the pace at which engineering is always changing.

When ECPD failed to accredit curricula, the boards of trustees and faculties responsible for their conduct realized that staff and equipment had not been kept up to date. When this realization occurred, there was practically unanimous co-operation on the part of all colleges in making the changes suggested. In some cases, the radical changes noted were brought about simply by a new esprit de corps, due to the addition of one or more new men to a faculty. In some cases the stimulus given by the inspection committee resulted in colleges obtaining increased floor space and some new equipment. Occasionally new buildings, fully equipped with new equipment, have been added, and very radical faculty changes and additions made. Indeed, the integrated results are such that ECPD can point with pride to the results of the accrediting program and assure students that the accredited curricula will provide for them proper instruction and equipment with which to work. Indeed, I am sure that some curricula not yet approved will receive approval as soon as reinspection can be accomplished.

The large number of engineering colleges spread all over the United States now giving satisfactory accredited engineering courses makes possible a good engineering education for almost everyone who is qualified to become an engineer and is willing to take the courses available. Indeed, the work of accrediting engineering curricula has been so well done that its high degree of perfection tends to promote indifference and even occasionally opposition to a continuation of the inspection program. The retention of the benefits obtained, however, by the inspection and accrediting program will require reinspection from time to time, as otherwise curricula and equipment in some engineering colleges will again be allowed to lag behind the growth of engineering industry until no longer up to the minimum desirable standard. As has been stated, "time marches on," and with it engineering changes occur. Engineering-college curricula, to be effective, must keep pace with, and in some phases lead, commercial engineering.

The number of men responsible for the conduct of ECPD is very small, and the task they have undertaken, as pointed out in President Doherty's report, is very great. Each of the other three committees, the committee on professional recognition, the committee on professional training, and the committee on student selection and guidance, has undertaken to guide a task as important as that of the committee on engineering schools, but, as stated in President Doherty's report, the projects supervised by these committees are not as specific as the work done by the committee on engineering schools. For that and other reasons, such as lack of financing, only the one project has made all the progress desired.

There is an old saying that runs something like this: "Men who do some things well can be depended upon to do all things well." The same is true of organizations. ECPD has proved its efficiency at the one job for which adequate funds were provided. It can be depended upon to do the others with our moral and financial support. Chairman Doherty is to be highly commended for the clear picture of what can and should be done. We owe him our thanks, and we owe ECPD our loyal support. I heartily endorse the report and urge that each of you devise ways for continuing the work thus far so ably done.

Future AIEE Meetings

Pacific Coast Convention
Yellowstone National Park, August 27–29 1941

South West District Meeting
St. Louis, Mo., October 8–10, 1941

Southern District Meeting
New Orleans, La., December 3–5, 1941

Winter Convention
New York, N. Y., January 26–30, 1942

Inspection and Pleasure Trips Feature Pacific Coast Convention

THE Pacific Coast convention will be held at Yellowstone National Park, August 27–29, 1941, with headquarters in the Canyon Hotel, near the Great Falls of the Yellowstone. This location in the midst of magnificent scenery enables members and guests to combine attendance at the convention with a delightful vacation. Besides the famous scenic features of the Park, all kinds of wild life may be seen from the highways.

TECHNICAL PROGRAM

Arrangements are being made for a technical program with a variety of interest. Four technical sessions have been tentatively scheduled: protective devices, basic sciences; power generation, transmission, and distribution; and selected subjects. The last-named session will have papers dealing with some of the latest scientific developments and with communication.

TRIPS

Among inspection trips that may be taken, the copper mines of Butte, Mont., will be open to visitors attending the convention. Located adjacent to the Continental Divide, they are "a mile high and a mile deep," and constitute a major source of copper, silver, zinc, and manganese. Because of the heat at these great depths one mine has been provided with a cooling system. Morrison Cave, located between Yellowstone Park and Butte, also may be visited. This cave has been recently opened to the public after several years' development by the Civilian Conservation Corps. Ranking as the third largest limestone cave in the United States, it is as yet known to very few.

For those driving to the convention, trips can be arranged to include Glacier Park, Grand Teton National Park, several major hydroelectric plants, Fort Peck Dam, rodeos, Indian reservations, Morrison Cave, mines and smelters, and historical spots at Virginia City, Bannock, and several Indian battlefields. Further information may be obtained from the convention publicity chairman, Clair F. Bowman, Helena, Mont.

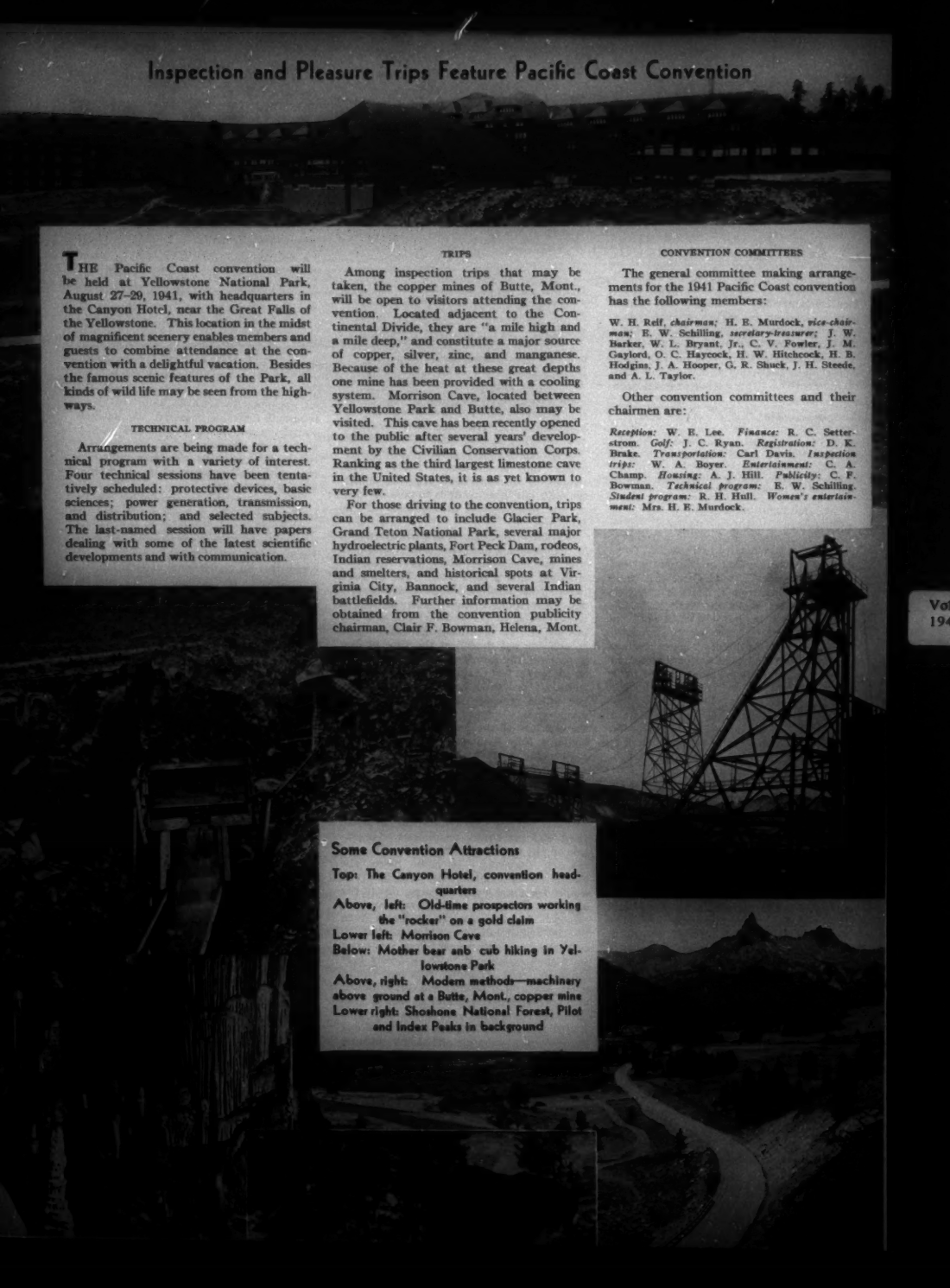
CONVENTION COMMITTEES

The general committee making arrangements for the 1941 Pacific Coast convention has the following members:

W. H. Reif, *chairman;* H. E. Murdock, *vice-chairman;* E. W. Schilling, *secretary-treasurer;* J. W. Barker, W. L. Bryant, Jr., C. V. Fowler, J. M. Gaylord, O. C. Haycock, H. W. Hitchcock, H. B. Hodgins, J. A. Hooper, G. R. Shuck, J. H. Steede, and A. L. Taylor.

Other convention committees and their chairmen are:

Reception: W. E. Lee. *Finance:* R. C. Setterstrom. *Golf:* J. C. Ryan. *Registration:* D. K. Brake. *Transportation:* Carl Davis. *Inspection trips:* W. A. Boyer. *Entertainment:* C. A. Champ. *Housing:* A. J. Hill. *Publicity:* C. F. Bowman. *Technical program:* E. W. Schilling. *Student program:* R. H. Hull. *Women's entertainment:* Mrs. H. E. Murdock.



Some Convention Attractions

Top: The Canyon Hotel, convention headquarters

Above, left: Old-time prospectors working the "rocker" on a gold claim

Lower left: Morrison Cave

Below: Mother bear and cub hiking in Yellowstone Park

Above, right: Modern methods—machinery above ground at a Butte, Mont., copper mine

Lower right: Shoshone National Forest, Pilot and Index Peaks in background

New Officers Announced at Summer Convention

Officers of the Institute for the year beginning August 1, 1941, were announced at the annual meeting held during the summer convention just concluded at Toronto, Canada. The report of the election was made by the committee of tellers. The new officers are:

President: D. C. Prince, manager, commercial engineering department, General Electric Company, Schenectady, N. Y.

Vice-Presidents: N. S. Hibshman, associate professor of electrical engineering, Lehigh University, Bethlehem, Pa. (District 2, Middle Eastern); J. E. Housley, superintendent of power, Aluminum Company of America, Alcoa, Tenn. (District 4, Southern); A. L. Jones, commercial vice-president and district manager, General Electric Company, Denver, Colo. (District 6, North Central); W. C. Smith, engineer, Pacific district, General Electric Company, San Francisco, Calif. (District 8, Pacific); C. A. Price, chief engineer, Canadian Westinghouse Company, Ltd., Hamilton, Ont., Canada (District 10, Canada).

Directors: L. A. Gamble, engineer in charge of electrical department, Washington Water Power Company, Spokane; T. G. LeClair, supervising development engineer, Commonwealth Edison Company, Chicago, Ill.; F. R. Maxwell, Jr., professor of electrical engineering, University of Alabama (temporarily at United States Naval Air Station, Pensacola, Fla.).

National Treasurer: W. I. Slichter, professor and head of the department of electrical engineering, Columbia University, New York, N. Y. (re-elected).

The board of directors for the administrative year beginning August 1, 1941, will consist of these newly elected officers and the following holdover officers:

R. W. Sorensen, Pasadena, Calif. (*retiring president*); F. M. Farmer, New York, N. Y. (*junior past president*); J. W. Barker, New York, N. Y.; T. F. Barton, New York, N. Y.; M. S. Coover, Ames, Iowa; M. Eldredge, Washington, D. C.; J. L. Hamilton, St. Louis, Mo.; K. L. Hansen, Milwaukee, Wis.; R. E. Hellmund, East Pittsburgh, Pa.; Everett S. Lee, Schenectady, N. Y.; L. R. Mapes, Chicago, Ill.; F. J. Meyer, Oklahoma City, Okla.; H. S. Osborne, New York, N. Y.; A. LeRoy Taylor, Salt Lake City, Utah; R. G. Warner, New Haven, Conn.

A detailed report of the 1941 summer convention will appear in the August issue.

Additions to List of Members for Life

Membership for life is granted by the AIEE to members who either have paid annual dues for 35 years, or have reached the age of 70 and have paid dues for 30 years. A list of those who have become members for life during the preceding year is published annually in ELECTRICAL ENGINEERING. The following are the Institute members who have reached member-for-life status since publication of the last previous list in the July 1940 issue.

Abbott, A. L.
Adams, H. H.
Adams, J. B.
Adams, R. W.
Allen, J. W.
Argersinger, R. E.
Armstrong, R. W.
Bickford, E. F.
Bishop, W. S.
Black, N. H.
Bragg, G. H.
Chatfield, C. E.
Coffin, F. P.
Cooper, A. T.
Corliss, C.
Cushing, H. M.
Darbee, W.
Del Mar, W. A.
Dennison, B. C.
Dibble, B.
Duncan, W. S.
Evans, H. S.
Farwell, F. M.
Fechheimer, C. J.
Ferguson, O. J.
Flowers, A. E.
Ford, J. H.
Gaenslen, C. A.
Gardiner, F. W.
Garrard, C. C.
Gehrkens, E. F.
Gibbes, T. M.
Gobel, F. C.
Goodwin, W. N.
Haas, H. C.
Haggerty, D. H.
Hall, G. C.
Hamilton, G. W.
Harding, C. F.
Harley, E. A.
Harris, F. W.
Hausmann, E. A.
Henderson, R. M.
Hilborn, D. S.
Holcombe, W. P.
Hudgson, J. H.
Jackson, W. A.
Jarvis, C. D.
Keith, L. S.
Kennedy, J. D.
Kenyon, O. A.
Knight, T. S.
Krass, R. W.
Lancaster, W. C.
Larrabee, H. D.
Lee, C.
Lester, B.
Liston, J.
Marriott, R. H.
McNitt, R. J.
Mead, D. W.
Merriam, E. B.
Mitchell, W. E.
Mossay, P. A.
Moultrop, I. E.
Murmann, F. J.
Murphy, E. M.
Nikonow, J. P.
Ofverholm, I.
Peiler, K. E.
Pender, H.
Pennell, W. O.
Petersen, P. C.
Philip, R. A.
Porter, R. A.
Powell, R. C.
Reed, T.
Rice, M. E.
Rochester, T. W.
Rucker, B. P.
Sands, H. S.
Scattergood, E. F.
Shreeve, H. E.
Shreve, E. O.
Skirrow, J. F.
Swoboda, A. R.
Thorpe, J. E. S.
Tritle, J. F.
Vassar, H. S.
Vincent, W. G.
Walker, F. W.
Waring, J. M. S.
Warren, W. A.
Weichsel, H.
Wendt, S. J.
Whisler, B. A.
White, H. E.
Wicks, J.
Wilder, C. W.
Willson, F. G.
Wood, R. J. C.
Woodruff, E. C.
Wooldridge, W. J.
Worcester, T. A.
Wright, W. F.

Board of Directors Meets

The regular meeting of the AIEE board of directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on May 23, 1941.

A report was made of the redecoration and refurnishment of certain rooms at Institute headquarters, previously authorized by the board of directors, and R. H. Hose, under whose direction the work was largely carried on as arranged by Chairman O. B. Blackwell of the headquarters committee, outlined the principles followed in this work.

Upon request of the members of the Section and approval of the Sections committee, the board authorized a change in name of the San Antonio Section to "South Texas Section."

J. F. Fairman, a representative of the Institute on the Engineers' Council for Professional Development, was present on behalf of Chairman R. E. Doherty of ECPD, during the discussion of Dr. Doherty's report entitled "ECPD Should Look Ahead." The board approved the publication of the report in full in ELECTRICAL ENGINEERING.

A draft of the annual report of the board of directors for the fiscal year ending April 30, 1941, as prepared under the direction of the national secretary, was approved for presentation at the annual meeting of the Institute, on June 17, subject to any changes suggested by members of the board prior to the printing date.

The board, upon recommendation of the standards committee, approved for publication a revision reported by the committee on electrical machinery of the proposed "Test Code for D-C Machines," to supersede the 1937 edition, and approved, for transmission to the American Standards Association, a proposed revision of the "American Standard for Graphical Symbols for Use on Drawings in Mechanical Engineering, Z32."

A report of the committee on award of Institute prizes on awards made for papers presented in 1940 was read and accepted. (The report was published in the June issue, page 287.)

The board confirmed applications to The Engineering Foundation for continued support, during the year beginning October 1, 1941, of the following research projects sponsored by the Institute: Project No. 66—Stability of Impregnated Paper Insulation; Project No. 74—Insulating Oils and Cable Saturants; Project No. 62—Welding Research.

An invitation to have a delegate present at the 175th anniversary celebration of Rutgers University, in New Brunswick, N. J., October 9–11, 1941, was referred to the president with power.

A report by Chairman C. R. Jones of the special committee which arranged, upon authorization of the board, for a series of radio talks on electrical engineering subjects, was presented and accepted with an expression of appreciation, the recommendations of the committee contained therein to be referred to the incoming board of directors.

The following actions were taken on appointments:

H. H. Henline reappointed national secretary of the Institute for the administrative year beginning August 1, 1941.

H. B. Gear reappointed representative of the Institute on the Washington Award Commission for the two-year term beginning June 1, 1941.

Appointment of a representative on the board of trustees of United Engineering Trustees, Inc., to fill a vacancy, referred to the president with power.

Appointment by the president of the following committee of tellers for 1941 election of Institute officers confirmed: **James H. Moore** (chairman), **J. E. Burroughs, H. H. Duehne, M. L. Gardner, P. P. Koliss, Woodman Perine, and Norman S. Spatz.**

Approval given to the appointments reported by the standards committee:

D. E. Renshaw, AIEE representative on the sectional Committee on Locomotives for Coal Mines, *M25*

H. M. Turner, AIEE representative on the Sectional Committee on Letter Symbols and Abbreviations for Science and Engineering, *Z10*

K. B. McEachron, chairman of the Sectional Committee on Lightning Arresters, *C62*

Other actions taken by the board included the following:

Executive committee actions on applications were confirmed as follows: As of March 8, 1941—43 applicants transferred and 16 elected to the grade of Member, 163 applicants elected to the grade of Associate, 147 Students enrolled; as of April 11, 1941—8 applicants transferred to the grade of Fellow, 9 applicants transferred and 11 elected to the grade of Member, 580 applicants elected to the grade of Associate, 204 Students enrolled.

Reports were presented and approved of meetings of the board of examiners held February 20, March 13, April 17, and May 22, 1941. Upon recommendation of the board of examiners, the following actions were taken: 6 applicants were transferred to the grade of Fellow; 8 applicants were transferred, 45 were elected, and one was reinstated to the grade of Member; 449 applicants were elected to the grade of Associate; 238 Students were enrolled.

Monthly expenditures were reported by the finance committee and approved by the board as follows: February, $28,744.35; March, $25,674.82; April, $27,774.85; May, $33,527.72.

The annual report of the national treasurer for the fiscal year ending April 30, 1941, was presented and approved.

Those present were:

President—R. W. Sorensen, Pasadena, Calif.

Past Presidents—F. Malcolm Farmer and John C. Parker, New York, N. Y.

Vice-Presidents—J. L. Hamilton, St. Louis, Mo.; Everett S. Lee, Schenectady, N. Y.; Fred R. Maxwell, Jr., Pensacola, Fla.; C. T. Sinclair, Pittsburgh, Pa.; A. LeRoy Taylor, Salt Lake City, Utah; J. M. Thomson, Toronto, Ont.; A. L. Turner, Omaha, Nebr.

Directors—C. R. Beardsley, H. S. Osborne, New York, N. Y.; M. S. Coover, Ames, Iowa; Mark Eldredge, Washington, D. C.; L. R. Mapes, Chicago, Ill.; D. C. Prince, Schenectady, N. Y.; R. G. Warner, New Haven, Conn.

National Treasurer—W. I. Slichter, New York, N. Y.

National Secretary—H. H. Henline, New York, N. Y.

By invitation—R. H. Hose and J. F. Fairman, of New York, were present during the discussion of certain subjects.

Contents of June 1941 Supplement

SUPPLEMENTING the technical papers that have been preprinted from the 1941 volume of AIEE TRANSACTIONS in the January–June, inclusive, monthly TRANSACTIONS sections of ELECTRICAL ENGINEERING, a June 1941 "Supplement to ELECTRICAL ENGINEERING—TRANSACTIONS Section" is being issued. This is the first midyear supplement to be issued under the provisions of the improved publication procedure adopted at the 1940 AIEE summer convention (*EE Aug. '40, p. 331–2*); it contains 39 technical papers and all discussions of these papers and of the papers preprinted in the January–June monthly sections.

Normally, the June 1941 supplement would have contained only some 200 pages. As the year 1941 is a transition year, however, in which many papers and related discussions accumulated under the provisions of the previous publication policy will be published several months earlier than would have been normal under the previous policy, the current supplement comprises a total of 450 pages. Likewise, the December 1941 supplement will be greatly oversize in order that the transition may be completed within the current year.

Copies of the June 1941 supplement will be mailed shortly to those who entered advance orders. Those who did not enter advance orders may obtain copies at 50 cents each from the AIEE order department, 33 West 39th Street, New York, N. Y., as long as the limited supply lasts.

Abstracts of most of the papers in the current supplement have appeared in the news pages of various issues of ELECTRICAL ENGINEERING, where they were published in advance of the meetings and conventions at which the papers were presented, in accordance with the provisions of the current publication policy. Brief abstracts of the remaining papers are given on this and the following page, these abstracts being taken directly from statements appearing in the respective papers.

Basic Sciences

40-108—Transient Analysis of Completely Transposed Multiconductor Transmission Lines; *Louis A. Pipes* (*A'37*). Abstracted in August 1940 issue, page 341.

40-109—Linear Transformations in Three-Phase Circuits; *Louis A. Pipes* (*A'37*). A general method of finding linear transformations to eliminate the coupling between substitutive networks is developed. The method is compared with that of symmetrical components and modified symmetrical components and its practical applicability discussed.

41-11—An Experimental Investigation of Subharmonic Currents; *John D. McCrumm* (*A'36*). Abstracted in January 1941 issue, page 34.

Communication

40-117—Aircraft Precipitation-Static Radio Interference; *E. C. Starr* (*M'29*). Radio reception at normal frequencies on board high-speed, all-metal aircraft suffers severe interference under certain precipitation conditions. Flight research has shown that under these same conditions, an airplane will accumulate a relatively heavy electric charge. The resulting potential difference between this charged object and its immediate surroundings creates voltage gradients of sufficient magnitude on pointed and sharp-edged extremities of the craft to produce corona discharges. Local radio disturbances of varying character and severe intensity accompany these discharges. The mechanism of the interference was studied intensively in the laboratory. Artificial airplane discharging devices involving trailing and projecting conductors terminating in special points and containing interference-suppressing resistors and inductors were developed.

40-118—High Voltage D-C Point Discharges; *E. C. Starr* (*M'29*). D-c corona discharges from pointed and sharp-edged conductors have been found to give rise to severe radio interference on aircraft under certain precipitation conditions. Laboratory studies, employing a point-to-plane arrangement, have shown that these discharges are greatly influenced not only by voltage and polarity but also by the geometry of the points. Three distinct types of positive and two of negative corona have been found. One of these types, that occurring on sharp, slender points, is essentially common to both polarities and is free from radio interference at all frequencies up to at least several megacycles. Those discharges common to rather bluntly backed points extend out some distance from the electrodes and are made up, in general, of a steady ion-migration component plus a series, orderly or otherwise, of ionic bursts. The latter phenomena, through an impulse excitation mechanism, give rise to the radio interference.

40-119—A Wide-Band Square-Wave Generator; *E. H. B. Bartelink* (*A'40*). A square-wave generator is described which covers a very wide frequency range, is compact, self-contained, and adaptable to many other uses besides the investigation of transient response. The instrument uses a positive-bias type multivibrator. The operation of the multivibrator and clipping circuits is explained. Approximate formulas for the multivibrator frequency and pulse width are derived and discussed and its increased stability against interference explained. Methods and fields for application are then discussed.

41-19—Inductive Co-ordination of REA Distribution Systems and Telephone Systems; *K. J. Plucknett* (*A'39*), *W. T. Smith* (*A'40*), *and T. A. Taylor* (*M'36*). Abstracted in January 1941 issue, page 35.

Diathermy

40-149—Short-Wave Diathermy Apparatus and Frequency-Control Possibilities; *C. K. Gieringer* (*A'35*). Abstracted in October 1940 issue, page 429.

Domestic and Commercial Applications

40-154—Design Factors Involved in the Design of Domestic Motored Appliances; *L. C. Packer* (*A'25*). Abstracted in October 1940 issue, page 429.

Electrical Machinery

40-120—Some Acceleration Tests on Large Synchronous Pump Motors; *R. W. Ager* (*A'24*). Abstracted in August 1940 issue, page 341.

40-135—A Generalized Equivalent Circuit in the Theory of Polyphase Commutator Motors; *W. B. Coulthard* (*M'34*). Abstracted in August 1940 issue, page 342.

40-138—The "Black Band" Method of Commutation Observation; *T. W. Schroeder* (*A'37*) *and John C. Aydelott* (*M'32*). Abstracted in September 1940 issue, page 373.

40-139—The Use of Auxiliary Impedances in the Single-Phase Operation of Polyphase Induction Motors; *Raymond W. Ager* (*A'24*). Abstracted in September 1940 issue, page 373.

40-151—Single-Phase Motor Theory—A Correlation of the Cross-Field and Revolving-Field Concepts; *C. T. Button* (*A'26*). Abstracted in October 1940 issue, page 429.

41-79—Protection of Power Transformers Against Lightning Surges; *AIEE Transformer Subcommittee.* Abstracted in January 1941 issue, page 36.

Industrial Power Applications

40-142—Two New Methods of Accelerating Electric Motors Automatically; *J. D. Leitch* (*A'38*). Abstracted in September 1940 issue, page 373.

40-148—Fault Voltage Drop and Impedance at Short-Circuit Currents in Low-Voltage

Circuits; *O. R. Schurig* (*M'18*). Abstracted in October 1940 issue, page 429.

Instruments and Measurements

40-128—Braking Magnets for Watt-Hour Meters; *I. F. Kinnard* (*M'28*) *and J. H. Goss* (*A'35*). Abstracted in August 1940 issue, page 342.

40-157—An Electrical Engine Indicator for Measuring Static and Dynamic Pressures; *E. J. Martin, C. E. Grinstead* (*A'40*), *and R. N. Frawley*. Abstracted in October 1940 issue, page 429.

Land Transportation

41-29—Complete Analysis of Motor-Temperature Rise; *Fremont Felix* (*M'32*) *and H. G. Jungk* (*M'40*). Abstracted in January 1941 issue, page 37.

Power Generation

40-143—Increased Capacity and Interconnections of the Columbia Gas and Electric Corporation; *C. W. DeForest* (*F'36*). Abstracted in October 1940 issue, page 430.

41-16—System Load Swings; *H. A. Bauman* (*M'41*), *O. W. Manz, Jr.*, (*M'34*), *J. E. McCormack* (*M'37*), *and H. B. Seeley* (*M'30*). Abstracted in January 1941 issue, page 38.

41-23—Effect of Prime-Mover Speed-Governor Characteristics on Power-System Frequency Variations and Tie-Line Power Swings; *C. Concordia* (*M'37*), *S. B. Crary* (*M'37*), *and E. E. Parker*. Abstracted in January 1941 issue, page 38.

41-68—Power System Governing—the Problem; *J. J. Dougherty* (*A'17*), *A. P. Hayward* (*A'30*), *A. C. Monteith* (*M'40*), *and S. B. Griscom* (*M'40*). Abstracted in January 1941 issue, page 38.

Production and Application of Light

40-156—Radiant Heat—a Full-Fledged Industrial Tool; *Paul H. Goodell* (*A'40*). Abstracted in October 1940 issue, page 430.

Protective Devices

40-86—Dielectric Strength of Water in Relation to Use in Circuit Interrupters; *J. Slepian* (*F'27*), *C. L. Denault* (*M'39*), *and A. P. Strom* (*M'39*). Water is generally considered to have the properties of an electrical conductor rather than those of an insulator. There are, however, a few applications where the dielectric rather than the conductive properties of water are of importance, as for example in its use as the interrupting liquid in circuit breakers. Here the water between electrodes must withstand full circuit voltage during the closing operation until the electrodes are in metallic contact, and also in the opening operation following extinction of the arc, until some auxiliary switch in series can open. Since there appears to be very little published information available on the subject, further knowledge of the behavior of water as a dielectric seemed to be of considerable interest and importance. To secure this information, a study of the subject was undertaken, the results of which are reported in this paper.

40-87—Harmonic-Current-Restrained Relays for Transformer Differential Protection; *C. D. Hayward* (*A'38*). Differential protection, employing percentage-differential relays, has long been the accepted method of fault protection for large power transformers. This method is quite satisfactory in most respects but is subject to false tripping on the transient magnetizing-inrush current which flows when the transformer is energized. This current, since it flows in only one winding of the transformer, causes a differential current to flows which, to an ordinary relay, "looks" the same as the current due to an internal fault. In this paper a new type relay is described which, using the principle of harmonic-current restraint, is able to distinguish between the differential current due to an internal fault and that due to magnetizing inrush, by their difference in wave form, operating with high speed on the fault current and being restrained from operating by the magnetizing inrush current. Minimum desensitization during the inrush period is obtained, depending on the relative magnitudes of the inrush and the fault currents.

40-114—The Vertical-Flow Interrupter and Its Application to "Oil-Poor" Circuit Breakers; *B. P. Baker* (*A'38*). Abstracted in August 1940 issue, page 342.

40-125—Medium Capacity Air-Blast Circuit Breakers for Metal-Clad Switchgear; *R. M. Bennett* (*M'37*) *and B. W. Wyman* (*A'40*). The cross-blast principle of arc interruption has been shown to provide maximum air economy; consequently this method of interruption is well suited for use in an air-blast breaker that must conform to the rigid space requirements and small phase spacings encountered in medium-capacity metal-clad equipment. It is shown that proper co-ordination of the operating mechanism, air supply, interrupting chamber, and resistor make possible a design to meet these requirements. The principle of operation is discussed and it is shown how a resistance is utilized to provide further air economy.

40-134—A Double-Break Oil- or Gas-Blast Power Fuse; *G. Leslie Hill* (*A'32*). Abstracted in August 1940 issue, page 342.

41-45—Power Arc-Over on Overhead Distribution Lines and Newly Developed Equipment for Protection Against Conductor Burndown From That Cause; *G. A. Matthews* (*A'40*). Abstracted in January 1941 issue, page 40.

41-61—The Geometry of Arc Interruption; *E. W. Boehne* (*M'37*). Abstracted in January 1941 issue, page 41.

Standards

41-31—Field Power-Factor Testing of Transformer Insulation and Operating Experience; *E. W. Whitmer* (*A'38*). Abstracted in January 1941 issue, page 42.

Transmission and Distribution

40-105—Abnormal Voltage Conditions in Three-Phase Systems Produced by Single-Phase Switching; *Edith Clarke* (*M'33*), *H. A. Peterson* (*A'35*), *and P. H. Light* (*A'36*). It has been recognized for some time that in three-phase circuits, high voltages may cause damage to equipment following the blowing of a fuse or the non-simultaneous opening or closing of switch contacts. With the renewed interest in fuses at high voltages, and the possibility of using single-pole switches, the problem of determining the conditions under which these devices may be safely used in circuits supplying ungrounded transformer banks has attained new importance. This paper gives the results of an investigation to determine the conditions under which high voltages may occur with one and two conductors open, with and without faults, and suggests rules for the application of fuses and single-pole switches. The phenomena discussed may be associated with any interrupting device having characteristics such that the time interval between the opening or closing of first and last phases is long enough to permit attainment of ultimate steady-state voltage conditions.

40-106—Arcing Faults in Power Systems; *C. Concordia* (*M'37*) *and H. A. Peterson* (*A'35*). For many years it has been recognized that voltage surges of considerable magnitude could be produced under certain system conditions by switching operations or by arcing faults. Such voltage surges have been studied in some detail in the past, and various theories have been developed to explain their occurrence to predict their magnitude. The theories were in most cases sound, but the prediction of surge magnitude was on a rather insecure basis. Within the past few years the study of the effect of switching operations in electric circuits has been greatly facilitated by the development of miniature circuits together with equipment for producing regularly recurrent switching and for indicating the resultant surge voltages and currents. This development has made it possible to re-examine on a more exact and physically consistent basis the various theories of intermittent switching and arcing, and to extend very much the range of possibilities investigated.

40-107—Shielding of Transmission Lines; *C. F. Wagner* (*F'40*), *G. D. McCann* (*A'38*), *and G. L. MacLane, Jr.* (*A'40*). Abstracted in August 1940 issue, page 342.

40-126—Capacitors and Circuit Performance; *J. W. Butler* (*M'38*). Abstracted in August 1940 issue, page 342.

40-133—Superposition Methods for Calculating Effects of Additions to Power Systems; *V. G. Rettig* (*A'32*). Abstracted in August 1940 issue, page 342.

Welding

40-146—The Application of Ignitrons to Resistance-Welding Control; *M. E. Bivens* (*A'40*). Abstracted in September 1940 issue, page 373.

Report of the Board of Directors

THE BOARD OF DIRECTORS of the American Institute of Electrical Engineers presents herewith to the membership its 57th annual report, for the fiscal year ending April 30, 1941. A general balance sheet showing the condition of the Institute's finances on April 30, 1941, together with other detailed financial statements, is included herein. This report contains a brief summary of the principal activities of the Institute during the year, more detailed information having been published from month to month in ELECTRICAL ENGINEERING.

BOARD OF DIRECTORS' MEETINGS

The board of directors held five meetings during the year, three in New York City, one in Swampscott, Mass., and one in Philadelphia, Pa.

The status of the committee on research was changed from that of a technical committee to that of a general committee. The names of two technical committees were changed, viz., the committee on applications to marine work became the committee on marine transportation, and the committee on transportation became the committee on land transportation.

Three new technical committees were established: committee on domestic and commercial applications, committee on air transportation, and committee on applications of electricity to therapeutics.

Information regarding many of the more important activities of the Institute which have been under consideration by the board of directors and the committees is published each month in the section of ELECTRICAL ENGINEERING devoted to Institute activities.

NATIONAL DEFENSE

Through a resolution adopted by the board of directors on June 27, 1940, the services of the Institute in connection with problems of national defense were offered to the President of the United States. At the meeting of the board of directors held on January 30, 1941, the new committee on air transportation was authorized to offer its services to the Army-Navy aeronautical board in connection with the development and co-ordination of aeronautical electrical equipment.

By actions of the board of directors, on January 30, 1941, an Institute committee on national defense was appointed, and Past President John C. Parker was designated to represent the Institute on the national technological civil protection committee appointed by the Secretary of War.

National committees have given increased attention to defense problems. The Sections have supplied information on engineering firms and individuals available for defense work of certain types. Many have included defense subjects in their programs.

President Sorensen is a member of the committee on acceleration of the regular engineering programs appointed by the Society for the Promotion of Engineering Education at the request of the advisory committee on defense training of the United States Office of Education. Many other officers and members of the Institute have been serving in defense activities.

President Sorensen and the headquarters staff have co-operated with Government divisions at every opportunity, assisting in several undertakings, including the national roster of scientific and specialized personnel. Messages from President Sorensen containing suggested ways in which engineers might aid the defense program have been published in ELECTRICAL ENGINEERING. Through the news columns of ELECTRICAL ENGINEERING, much information on problems of national defense has been supplied to the membership.

PRESIDENT'S AND NATIONAL SECRETARY'S VISITS

President Sorensen and National Secretary Henline attended the summer and Pacific Coast conventions, the winter convention, the Middle Eastern District meeting in Cincinnati, Ohio, and the North Eastern District meeting in Rochester, N. Y. They also visited many Sections and Student Branches. During May, they will visit the following Sections: Washington, North Carolina, West Virginia, and Cincinnati; and President Sorensen will visit the Cleveland Section. President Sorensen and National Secretary Henline will attend the summer convention in Toronto, Ont., Canada.

The places visited by President Sorensen follow:

Alabama
- Alabama Section, Birmingham
- Muscle Shoals Section

California
- Pacific Coast convention, Los Angeles
- Los Angeles Section, University of Southern California Branch, and California Institute of Technology Branch, at U.S.C.
- San Francisco Section
- Conference on student activities, Districts Nos. 8 and 9, and University of British Columbia, Los Angeles

Colorado
- Denver Section
- University of Colorado Branch, Boulder
- Colorado State College, Ft. Collins
- Conference on student activities, North Central District, No. 6, University of Denver; 9 Branches represented

Georgia
- Georgia Section, Atlanta
- Georgia School of Technology Branch, Atlanta

Illinois
- Chicago Section
- Illinois Institute of Technology Branch, Chicago
- Northwestern University, Evanston

Idaho
- University of Idaho, Moscow

Indiana
- Central Indiana Section, Indianapolis
- Fort Wayne Section
- Purdue University, Lafayette

Iowa
- Iowa Section, Cedar Rapids
- Iowa State College Branch, Ames

Kentucky
- Louisville Section
- University of Kentucky Branch, Lexington

Massachusetts
- Summer convention, Swampscott
- Boston Section
- Lynn Section executive committee meeting
- Worcester Section and Worcester Polytechnic Institute Branch, at W.P.I.

Michigan
- Michigan Section, Detroit

Minnesota
- Minnesota Section, Minneapolis
- University of Minnesota, Minneapolis

Missouri
- Kansas City Section
- St. Louis Section
- University of Missouri Branch, Columbia

Montana
- Montana Section and Montana State College Branch, joint meeting, Butte

Nebraska
- Nebraska Section, Omaha
- University of Nebraska, Lincoln

New York
- Cornell University, Ithaca
- Ithaca Section
- Syracuse Section
- Syracuse University Branch
- North Eastern District meeting, Rochester
- North Eastern District conference on student activities, Rochester, 17 Branches represented

Ohio
- Middle Eastern District meeting, Cincinnati
- Toledo Section
- Columbus Section
- Ohio State University, Columbus

Oklahoma
- Oklahoma City Section
- Tulsa Section

Oregon
- Portland Section

Pennsylvania
- Winter convention, Philadelphia
- Pittsburgh Section, and University of Pittsburgh, Carnegie Institute of Technology, and West Virginia University Branches, joint meeting, Pittsburgh
- Pittsburgh Section student conference
- Erie Section

Rhode Island
- Providence Section
- Brown University Branch, Providence

South Carolina
- South Carolina Section, Columbia

Tennessee
- East Tennessee Section, Athens

Texas
- New Mexico-West Texas Section, El Paso

Utah
- Utah Section, Salt Lake City
- University of Utah, Salt Lake City

Washington
- Seattle Section
- University of Washington, Seattle
- Spokane Section, and University of Idaho and Washington State College Branches, joint meeting, Spokane
- Washington State College, Pullman

Wisconsin
- Madison Section
- University of Wisconsin, Madison
- Milwaukee Section

Canada
- Toronto Section

The places visited by the national secretary are the following:

Alabama
- Alabama Section, Birmingham
- Muscle Shoals Section

California
- Pacific Coast convention, Los Angeles
- Conference on student activities, Districts 8 and 9, and University of British Columbia, Los Angeles

District of Columbia
- Washington Section

Georgia
- Georgia Section, Atlanta

Illinois
- Illinois Institute of Technology Branch, Chicago
- Northwestern University, Evanston

Indiana
Central Indiana Section, Indianapolis
Purdue University, Lafayette

Kentucky
Louisville Section
University of Kentucky Branch Lexington

Massachusetts
Summer convention, Swampscott, Mass.
Boston Section
Lynn Section executive committee meeting
North Eastern District executive committee meeting, Pittsfield

Michigan
Michigan Section, Detroit

Missouri
Kansas City Section
St. Louis Section

Nebraska
Nebraska Section, Omaha
University of Nebraska Branch, Lincoln

New Jersey
Student Branch convention, District No. 3, New Brunswick

New York
Cornell University, Ithaca
New York Section
Ithaca Section
Syracuse Section
Manhattan College Branch, New York
New York Section student convention, Rutgers University, New Brunswick, N. J.
North Eastern District meeting, and conference on student activities, Rochester, N. Y.
District No. 3 Branches, smoker, Pratt Institute, Brooklyn, N. Y.

Ohio
Middle Eastern District meeting, Cincinnati
Conference on student activities, Middle Eastern District, No. 2, Cincinnati

Pennsylvania
Pittsburgh Section, and University of Pittsburgh, Carnegie Institute of Technology, and West Virginia University Branches, joint meeting, Pittsburgh
Pittsburgh Section, student conference
Winter convention, Philadelphia

Rhode Island
Providence Section
Brown University Branch, Providence

South Carolina
South Carolina Section, Columbia

Tennessee
East Tennessee Section, Athens

Canada
Toronto Section

ANNUAL MEETING

The annual business meeting of the Institute was held on Monday morning, June 24. The annual report of the board of directors for the fiscal year which ended April 30, 1940, was presented in abstract by the national secretary. A report on the finances of the Institute was presented by National Treasurer W. I. Slichter. The report of the committee of tellers upon the election of officers for the year beginning August 1, 1940, was presented, and President-Elect Sorensen responded to his introduction with a brief address. During this session, special honors were accorded to Charles L. Clarke, charter member of the Institute, and the Lamme Medal for 1939 was presented to Norman W. Storer, retired consulting engineer, Westinghouse Electric and Manufacturing Company.

NATIONAL CONVENTIONS

Three national conventions were held during the year, and a brief report on each follows:

Summer Convention. The 50th summer convention was held in Swampscott, Mass., June 24–28, 1940. In addition to the annual business meeting, conference of officers, delegates, and members, there were 10 technical sessions, at which 41 papers were presented, 1 general session, demonstration on frequency modulation, and 6 technical conferences. The general session was in collaboration with the American Engineering Council, under the leadership of its president Colonel Alonzo J. Hammond, and consisted of addresses by Colonel William J. Wilgus and Colonel Robert F. Henry on the topic "Transportation as a Social Problem". Entertainment features of the convention were women's tea and musicale, bridge, dance, banquet, golf and tennis tournaments. Many inspection trips were held. The registration was 1,014.

Pacific Coast Convention. The 28th Pacific Coast convention was held in Los Angeles, Calif., August 27–30, 1940, with a registration of 465. In addition to 4 technical sessions at which 16 papers were presented, there was a joint session with the Institute of Radio Engineers, informal conference, 2 student sessions with 10 technical papers, and a conference on student activities. Entertainment features included reception and dancing, banquet, inspection trips, golf tournament, and ladies' events.

Winter Convention. The 29th winter convention was held in Philadelphia, Pa., January 27–31, 1941, with a program including 20 sessions with 82 papers, and 9 technical conferences. Speakers on general subjects were: Charles E. Wilson, president, General Electric Company, and R. D. Evans, Massachusetts Institute of Technology. At an evening meeting, the Edison Medal was presented to Doctor George A. Campbell, retired research engineer, Bell Telephone Laboratories, Inc. A smoker, dinner-dance, women's bridge, and numerous inspection trips completed the program. The registration was 1,931.

DISTRICT MEETINGS

Middle Eastern District Meeting. The 11th meeting of this District was held in Cincinnati, Ohio, October 9–11, 1940. The meeting included 5 sessions at which 25 technical papers were presented, 2 technical conferences, meetings of the Student Branch counselors and executive committee. Entertainment features consisted of smoker, luncheons, informal dinner, women's events, and numerous inspection trips. The attendance was 599.

North Eastern District Meeting. An interesting and varied program for this meeting in Rochester, N. Y., April 30–May 2, 1941, included 5 sessions at which 8 addresses and 14 technical papers were presented, 1 session for graduate student papers, 2 sessions for undergraduate papers, a District executive committee luncheon, a Branch counselors' and students' luncheon, a banquet, a smoker, inspection trips, and women's events. The attendance was 355.

SECTIONS

Two new Sections, Arizona and South Bend, were organized; and the names of two Sections were changed to make them more accurately descriptive of the territories: Charleston to West Virginia, and El Paso to New Mexico-West Texas.

As indicated in the list of his visits, President Sorensen visited a large number of Sections. In most cases, he gave an address entitled "Engineering Horizons, Limited," illustrated with many lantern slides. This proved to be an unusually interesting and instructive address, as shown by the close attention of all audiences and a great many highly complimentary comments received by the national secretary.

The Sections again held a larger number of meetings than reported for any previous year. Interest in technical groups, special technical meetings, and so on, continued at a high level, and attendance at such meetings was excellent.

Two Sections reported no activity; 8 Sections held more than 15 meetings each, 9 held from 12 to 15, 38 held from 8 to 11, 10 held from 4 to 7, and 6 held from 1 to 3.

The plan adopted several years ago to include within Section territories, in so far as practicable, all Institute members within the United States resulted in the revision of the territories of a considerable number of Sections. The August 1, 1940, record of Section membership showed the total membership of Sections in the United States as 14,338. In September, it was found that only 93 members in the United States were outside Section territories. The Sections committee has continued its study of unassigned territory with the object of recommending further revisions when desirable.

The other activities of the Sections committee have included the adoption of a trial plan for publishing information on Section meetings in ELECTRICAL ENGINEERING, plans to develop greater interest among the Sections in vocational guidance, and efforts to develop more effective distribution of the pamphlets "The Electrical Engineer" and "Engineering—A Career, a Culture".

Table I contains information regarding Sections and Branches and their meetings during the past several years. Detailed information on their activities of the past year may be found in the annual report on Section and Branch activities in the June issue of ELECTRICAL ENGINEERING, pages 285–7.

Table I. Section and Branch Statistics

	For Fiscal Year Ending April 30					
	1936	1937	1938	1939	1940	1941
Sections						
Number of Sections	61	62	65	67	70	72
Number of meetings held	540	621	624	635	701	703
Total attendance	85,501	74,950	110,148	85,692	91,949	92,554
Branches						
Number of Branches	118	119	120	120	121	123
Number of meetings held	1,045	1,363	1,334	1,190	1,346	1,163
Total attendance	45,304	46,121	60,446	53,380	64,972	52,285

STUDENT BRANCHES

New Student Branches organized at the University of Connecticut, Norwich University, and Manhattan College, and the combination of the Armour Institute of Technology and the Lewis Institute Branches into the Illinois Institute of Technology Branch brought the total number at the end of the year to 123.

President Sorensen visited a considerable number of Branches, and his addresses were enthusiastically received.

Only one Branch failed to report any activity. Thirteen held more than 15 meetings each, 30 held from 8 to 11, 36 held from 4 to 7, and 16 held from 1 to 3, with a total number of 1,163 meetings, as compared with 1,346 for the preceding year; 1,190 for 1938–39; and 1,334 for 1937–38. The number of talks by students, 608, was materially below the totals for recent years: 767 for 1939–40, 725 for 1938–39, and 897 for 1937–38.

Students have continued to present technical papers at the Pacific Coast convention and various District meetings. In general the quality of presentation has been excellent, and large numbers of students have attended such sessions.

The terms of 1,641 enrolled students were expected to expire on April 30, 1941. Of these, 887 or about 54 per cent applied for admission as Associates.

See references at end of the preceding report on Sections.

General Committees

FINANCE COMMITTEE

In the preparation of the budget for the year, the finance committee made allowance for expected losses of dues revenues, and subscriptions normally received from abroad. In spite of this, due primarily to increased memberships in this country, estimated revenues for the budget year, beginning October 1, are about $10,000 greater than for last year. This permits a further modest expansion in the Institute's activities. The budget this year also provides for a nonrecurring expense due to placing in effect a revision in the publication program by means of which publications of some of the TRANSACTIONS material is made at an earlier date than under the former policy. Details of the budget and a further discussion of it are included in the December 1940 issue of ELECTRICAL ENGINEERING.

The conservation of the Institute's investment funds is a problem of increasing difficulty. Under advice of investment counsel and the finance committee, the board of directors this past year approved putting about ten per cent of the Institute's investment funds in common stocks. While this is a new departure for the Institute it is following in a direction which has been taken by many educational and professional organizations.

Haskins and Sells, certified public accountants, have audited the Institute books and their report appears on pages 348–50.

TECHNICAL PROGRAM COMMITTEE

Convention Program. Three national conventions and two District meetings were held during the year. The total attendance of these five meetings represents a 22.3 per cent increase over that for the previous year.

Table II. Technical Programs, Last Three Years

	Year Ending April 30		
	1941	1940	1939
Number of national conventions	3	2	3
Number of District meetings	2	3	3
Registration at national conventions and District meetings	4,330	3,548	4,100
Number of papers presented	195	177	184
Number of papers recommended for TRANSACTIONS	164	151	169
Estimated number of pages required for printing papers in TRANSACTIONS	938*	886*	986*
Average length of papers recommended for TRANSACTIONS	5.72	5.86	5.83
Number of technical sessions	46	43	50
Number of technical conferences	18	10	12

* Partly estimated.

This has not been the result of an unusually large attendance at any one particular meeting, but the attendance at three of the meetings each establishes a record over corresponding meetings in those localities, and the attendance at the summer convention was substantially above the average attendance for summer conventions of the past ten years. The policy of presenting enlarged programs has been continued, and the attached table of statistics shows that 8 more technical conferences were held during the past year than for the previous year. The technical program for the winter convention was also enlarged to include 2 more technical sessions and 1 more technical conference than have ever been held heretofore. While the attendance at meetings and conventions is a variable depending on several factors, such as location, time of the year, the entertainment program, and general business conditions, it was nevertheless believed that the size and character of the technical programs has contributed in no small measure to the success of these meetings. Many of the papers presented at these meetings were of a high order and favorable comments were received.

Technical Conferences. The increased number of technical conferences has proved beneficial in several ways. The standards co-ordinating committees have been able to obtain a broad cross-section of views preliminary to the adoption or revision of certain standards. The conferences also have served as a trial or proving ground for the development of papers of a high quality which were scheduled later for formal presentation and discussion. Committees on basic sciences, power generation, and standards all have developed some papers in this manner.

Oral Presentations. A letter suggesting ways and means of increasing the effectiveness of the oral presentations was sent to each author and presiding officer of the winter-convention sessions. The suggestions were compiled from a canvass of authors and presiding officers of a previous convention and many of the oral presentations were improved. It has been decided to send a revised version of this letter to the authors on subsequent convention programs.

General Sessions. General sessions which were held at both the winter and summer conventions proved to be very successful, and arrangements are being made to hold another at the 1941 summer convention in Toronto. Preference has been indicated for suitable subject matter to lean more toward the broader problems of human relationships or the social aspects of the profession as related to co-operative effort during and after changed world conditions, rather than the more specific technical developments.

Trends in Policy. The modified publication procedure, announced in the August 1940 issue of ELECTRICAL ENGINEERING, has worked out satisfactorily from the standpoint of program development. Selling pamphlet copies at an increased price according to their lengths has not reduced the number of copies placed in circulation for the purpose of discussion at the various meetings. The proposal to give preference to papers 6 pages or less in length in the TRANSACTIONS section of ELECTRICAL ENGINEERING has provided an incentive for the authors to produce shorter papers. The data in the accompanying table shows that the papers for the past year were of an estimated average length of 5.72 pages, as compared with 5.86 pages for the previous year, before the incentive was provided. The reduction in average page length per paper will be still greater when the policy has been in effect over the full year.

The national defense program has resulted in a scarcity of papers in certain fields, such as industrial, automatic control, and communications. Some papers have also been held up by a more careful scrutiny pending company release and approval. Increase in the pace of industry has also impaired the prompt functioning of the committees as well as the authors in the reviewing and writing of papers to meet certain dates. However, there is no immediate scarcity of good papers in the central-stations fields of activities.

Acknowledgments. The committee wishes gratefully to acknowledge the interest and efforts of its members, the chairmen of the technical committees, and the members of the headquarters staff in the conduct of the work.

PUBLICATION COMMITTEE

ELECTRICAL ENGINEERING and TRANSACTIONS were published during the fiscal year largely on the basis of the same general publication policy and procedure as for the preceding year.

Modifications in publication procedure during the past year include the establishment of the "Supplement to ELECTRICAL ENGINEERING—TRANSACTIONS Section" on a semiannual instead of on an annual basis, and the transfer of the publication of discussions from the monthly periodical to the Supplement.

The principal effort of the year in improving the publication service to the Institute's members has been directed toward reducing the time delay between presentation and publication of technical papers and discussions. The omission of discussions from the monthly issues has enabled a progressively earlier publication of technical-

Table III. Membership Statistics for the Fiscal Year Ending April 30, 1941

	Honorary	Fellow	Member	Six-Year Associate	Associate	Total
Membership on April 30, 1940	8	767	4,495	5,724	6,219	17,213
Additions:						
Transferred		34	182	612		
New members qualified		2	129	35	1,435	
Former members reinstated			9	18	16	
	8	803	4,815	6,389	7,670	19,685
Deductions:						
Died		20	36	22	12	
Resigned		3	44	128	124	
Transferred			34	156	638	
Dropped		2	51	193	336	
		25	165	499	1,110	1,799
Membership on April 30, 1941	8	778	4,650	5,890	6,560	17,886

program papers, and has also enabled the monthly pages otherwise required for discussion to be used for additional technical-program papers.

This will help materially to reduce the time delay in making available in published form the technical papers not included in the monthly issues and the approved discussion of all papers.

When the expediting program was initiated in the early summer of 1940, the publication of 1940 winter convention papers in any quantity could not begin until the June issue, and this, of course, determined the time schedule for the papers of all later conventions during the year. The objective is that by January 1942 the publication of winter convention papers should begin in January and be completed in June, with papers from the other conventions being scheduled accordingly. On the basis of this program, the 1942 TRANSACTIONS is scheduled to be a record of 1942 technical-program papers, instead of embracing parts of at least two years as heretofore. As of the date of this report, this expediting program is proceeding on schedule, but, of course, involves the handling of an increased amount of material during the period of transition. This is evidenced in the enlarged size of the 1940 Supplement, and will be shown also in the enlarged Supplements for June and December 1941. Adjustments of publication schedule between the monthly and annual publications have enabled this transition to be met without imposing an undue burden on the budget.

Another modification in publication policy that became effective during the year was an increase in the price of the advance pamphlet copies of technical program papers as produced for conventions and District meetings. Although this pamphlet-copy program still is underwritten by the general publication budget, the effort and trend are toward making this special service more nearly self-supporting.

MEMBERSHIP COMMITTEE

The membership committee, at its first meeting on September 24, 1940, decided upon a program for its activities during the year, which included a study of all practicable means by which membership work of the Institute, including that in the Sections, might be better co-ordinated in a manner to improve its effectiveness. The committee had in mind more the means by which the national committee could be of greater assistance to the Section membership committees through furnishing information as to the most effective methods and procedures, rather than by endeavoring to establish any uniform procedures.

A subcommittee appointed to study this general problem reported the conclusion that the most important contribution which the national committee could make to the membership work in the Sections was the preparation and issuance of a membership committee guide, containing its recommendations for the conduct of membership committee work. It was felt that this would provide a continuing means of pooling the experience of Section membership committees throughout the Institute territory, since the guide would be revised and improved from time to time, and this information would be valuable to new membership committees. The reaction to this proposal was favorable and a membership committee guide was prepared, approved at the meeting of the committee on January 31, and issued in final form on March 31. Copies were sent to all Section membership committees and to the chairmen of all Sections.

To improve the effectiveness of the national committee in administering the membership work of the Institute, the following measures were adopted:

(*a*). Due to the wide distribution of members of the committee, frequent well-attended meetings are impracticable. Since the best interests of the committee demand the prompt disposal of matters which continuously arise, an advisory subcommittee, composed of six members of the committee in or near New York, was appointed to function as a sort of executive committee, meeting with the chairman as frequently as may be necessary to dispose of matters that cannot be held for the regular committee meetings.

(*b*). A research subcommittee, composed of six other members of the committee, was appointed to deal with problems requiring extensive study and research, and to develop recommendations as to fundamental problems which arise.

To improve the co-ordination of Section membership committee work along the most effective lines, District vice-chairmen of the membership committee have been encour-

Table IV. Number of Applications Received From Enrolled Students and From All Others

Year Ending April 30	Students	All Others	Total
1941	887	1,011	1,898
1940	911	918	1,829
1939	849	872	1,721
1938	739	932	1,671
1937	716	1,040	1,756

Table V. Number of Enrolled Students, as of April 30

Year	New Applications	Renewals	Total
1941	2,351	3,188	5,539
1940	2,525	2,992	5,517
1939	2,271	2,971	5,242
1938	2,428	2,609	5,037
1937	2,249	2,254	4,503

Table VI. Number of Members in Section Territory Reinstated

August 1, 1940 to April 30, 1941	331
Year beginning August 1, 1939	302
Year beginning August 1, 1938	354
Year beginning August 1, 1937	325
Year beginning August 1, 1936	503

Table VII. Status of Membership Dues, as of April 30

Year	Total Membership	Members Fully Paid	
		Number	Per Cent
1941	17,886†	15,777	88.2
1940	17,213	14,997	87.1
1939	16,605	14,371	86.5
1938	16,078	14,127	87.9
1937	15,308	13,439	87.8
1927*	18,344	16,247	88.6

* Year of maximum membership.

† Of the 17,886 members reported for April 30 1941, 2,109 were not fully paid to April 30, 1941. These are divided into:

1. Members owing dues to April 30, 1940 . . . . 627 (Total number of members who have not acted upon resolution of board of directors adopted in January 1941 providing an extension of time for payment of dues.)

2. Members owing dues to April 30, 1941 . . . 1,482 (During the period May 1 to May 16, 1941, 325 members have paid dues to April 30, 1941, reducing the number not fully paid to 1,157.)

Table VIII. Record of AIEE Membership

Year	Total May 1	Year	Total May 1	Year	Total May 1
1884	71	1904	3,027	1923	15,298
1885	209			1924	16,455
1886	250	1905	3,400		
1887	314	1906	3,870	1925	17,319
1889	333	1907	4,521	1926	18,158
		1908	5,674	1927	18,344
1890	427	1909	6,400	1928	18,265
1891	541			1929	18,133
1892	615	1910	6,681		
1893	673	1911	7,117	1930	18,008
1894	800	1912	7,459	1931	18,334
		1913	7,654	1932	17,550
1895	944	1914	7,876	1933	17,019
1896	1,035			1934	15,230
1897	1,073	1915	8,054		
1898	1,098	1916	8,202	1935	14,369
1899	1,133	1917	8,710	1936	14,600
		1918	9,282	1937	15,308
1900	1,183	1919	10,352	1938	16,078
1901	1,260	1920	11,345	1939	16,605
1902	1,549	1921	13,215	1940	17,213
1903	2,229	1922	14,263	1941	17,886

Table IX. Deaths of AIEE Members Reported During the Year Ending April 20, 1941

Name	Date of Election	Date of Death	Grade at Death	Obituary Notice in ELECTRICAL ENGINEERING
Archils, F.	Associate '29	Dec. 3, 1940	Associate	Feb. 1941, p. 89
Barry, R. J.	Associate '10	Mar. 4, 1940	Member	July 1940, p. 309
Blakeslee, H. J.	Associate '02	Jan. 19, 1941	Member	Mar. 1941, p. 141
Bostwick, H. M.	Associate '21	Nov. 25, 1940	Associate	Feb. 1941, p. 89
Boyrer, W. C.	Associate '09	Sept. 28, 1940	Fellow	Nov. 1940, p. 473
Brown, W. E.	Associate '02	May 13, 1940	Associate	Sept. 1940, p. 376
Bush, R. F.	Associate '08	Sept. 6, 1940	Associate	Dec. 1940, p. 519
Capen, W. H.	Member '23	Jan. 13, 1941	Member	Mar. 1941, p. 141
Carson, J. R.	Associate '19	Oct. 31, 1940	Fellow	Dec. 1940, p. 519
Colville, F. P.	Member '30	July 20, 1940	Member	Sept. 1940, p. 376
Cosandey, C. J.	Associate '27	1940	Associate	Sept. 1940, p. 376
Crapo, C. A.	Member '23	Sept. 2, 1940	Member	Nov. 1940, p. 474
Degen, Lewis	Associate '95	Dec. 22, 1940	Member	Feb. 1941, p. 88
Dill, G. C.	Associate '13	Apr. 1, 1940	Member	June 1940, p. 258
Dyer, R. I.	Associate '99	Feb. 4, 1939	Associate	Feb. 1941, p. 89
Ferguson, L. A.	Associate '01	Aug. 25, 1940	Fellow	Oct. 1940, p. 433
Fitzgerald, T. W.	Associate '15	Feb. 20, 1941	Member	Apr. 1941, p. 184
Freedman, W. H.	Associate '90	1941	Fellow	Apr. 1941, p. 183
Fuller, A. G.	Associate '37	Mar. 11, 1940	Associate	Dec. 1940, p. 520
Garrels, W. L.	Associate '95	1940	Associate	Sept. 1940, p. 376
Gibbs, George	Associate '05	May 20, 1940	Fellow	July 1940, p. 308
Gill, W. T.	Associate '31	Jan. 28, 1941	Associate	Apr. 1941, p. 184
Graff, J. T.	Associate '21	Mar. 18, 1940	Member	June 1940, p. 257
Greenidge, C. A.	Associate '03	Jan. 23, 1941	Fellow	Mar. 1941, p. 141
Halpin, L. C.	Associate '26	Dec. 11, 1939	Associate	July 1940, p. 310
Hardie, C. G.	Member '30	Oct. 18, 1940	Member	Jan. 1941, p. 46
Hegy, Joseph	Associate '38	Nov. 5, 1938	Associate	Dec. 1940, p. 520
Heitman, Edward	Associate '00	Sept. 25, 1940	Fellow	Jan. 1941, p. 45
Henry, I. W.	Associate '01	April 23, 1940	Member	June 1940, p. 257
Hicks, L. R.	Associate '12	Aug. 29, 1940	Member	Oct. 1940, p. 434
Higson, C. R.	Associate '21	Dec. 18, 1940	Member	Mar. 1941, p. 141
Hill, J. B.	Associate '10	Jan. 19, 1941	Member	Apr. 1941, p. 183
Hoge, C. H.	Associate '19	Jan. 12, 1941	Member	Apr. 1941, p. 184
Ittin, David	Associate '30	Aug. 21, 1939	Associate	Aug. 1940, p. 346
Kiefer, K. J.	Associate '36	Mar. 9, 1940	Associate	Nov. 1940, p. 474
Knowlton, F. K.	Member '25	Dec. 1939	Member	July 1940, p. 309
Kyne, S. B.	Associate '37	Aug. 21, 1940	Associate	Nov. 1940, p. 474
Lagomasino, Julio	Associate '38	1940	Associate	June 1940, p. 258
McAnge, W. N.	Associate '25	Aug. 30, 1940	Member	Dec. 1940, p. 519
McCulloch, Richard	Associate '04	Aug. 27, 1940	Member	Jan. 1941, p. 45
McPherson, N. C.	Associate '03	Oct. 15, 1939	Associate	July 1940, p. 309
Merz, C. H.	Associate '95	Oct. 1940	Fellow	Dec. 1940, p. 519
Montgomery, L. J.	Associate '18	Jan. 21, 1941	Associate	Apr. 1941, p. 184
Moody, V. D.	Associate '99	May 30, 1940	Fellow	July 1940, p. 309
Motter, H. W.	Associate '18	May 30, 1940	Member	Aug. 1940, p. 346
Nixon, R. O.	Associate '22	Dec. 25, 1940	Associate	Feb. 1941, p. 89
Northrup, E. F.	Associate '01	Apr. 29, 1940	Fellow	June 1940, p. 257
Parmenter, R. J.	Associate '17	July 26, 1940	Member	Sept. 1940, p. 376
Pennell, R. R.	Associate '34	1940	Associate	July 1940, p. 310
Phillips, L. A.	Associate '94	Dec. 9, 1940	Fellow	Feb. 1941, p. 88
Powell, A. L.	Associate '13	Aug. 21, 1940	Fellow	Oct. 1940, p. 433
Prowse, R. M.	Associate '39	Feb. 11, 1940	Associate	Feb. 1941, p. 89
Quirk, W. G.	Associate '16	Sept. 10, 1939	Member	Dec. 1940, p. 520
Rappel, U. J.	Member '35	Sept. 24, 1940	Member	Mar. 1941, p. 141
Rapport, A. H.	Associate '30	Dec. 17, 1940	Member	Feb. 1941, p. 89
Robbins, H. A.	Associate '08	Oct. 25, 1940	Member	Dec. 1940, p. 520
Roberts, Sheldon	Associate '25	Apr. 21, 1940	Associate	July 1940, p. 309
Rugg, W. S.	Associate '02	Apr. 25, 1940	Member	June 1940, p. 257
Rushmore, D. B.	Associate '95	May 5, 1940	Fellow	June 1940, p. 257
Scharnberg, H. J. B.	Associate '18	Nov. 1940	Member	Jan. 1941, p. 45
Seiden, A. K.	Associate '03	Oct. 3, 1940	Associate	Apr. 1941, p. 184
Smith, R. T.	Member '19	Apr. 28, 1940	Member	July 1940, p. 309
Stephanus, A. D.	Member '28	Jan. 3, 1940	Member	July 1940, p. 309
Sticht, H. H.	Associate '13	Feb. 11, 1940	Member	July 1940, p. 309
Stickney, Oswald	Associate '32	Apr. 29, 1940	Associate	July 1940, p. 310
Stillwell, L. B.	Associate '02	Jan. 19, 1941	Fellow	Feb. 1941, p. 88
Stone, C. A.	Associate '91	Feb. 25, 1941	Member	Apr. 1941, p. 183
Strong, J. R.	Associate '01	Oct. 25, 1940	Associate	Jan. 1941, p. 46
Styff, Eivind	Associate '23	1940	Member	Oct. 1940, p. 434
Towne, R. M.	Associate '36	May 24, 1940	Associate	Aug. 1940, p. 346
Uebelacker, C. F.	Associate '90	Sept. 17, 1940	Member	Nov. 1940, p. 473
Wegrin, J. W.	Associate '29	Nov. 26, 1939	Associate	Aug. 1940, p. 346
White, W. S.	Associate '39	May 7, 1940	Associate	Sept. 1940, p. 376
Winter, W. W.	Associate '38	Dec. 11, 1939	Associate	July 1940, p. 310
Wise, D. M.	Member '37	Jan. 8, 1941	Member	Mar. 1941, p. 141
Woodrow, H. R.	Associate '12	Aug. 12, 1940	Fellow	Sept. 1940, p. 375
Woolfenden, H. L.	Associate '17	Jan. 19, 1941	Member	Apr. 1941, p. 184
Wright, R. I.	Associate '04	Jan. 4, 1941	Fellow	Apr. 1941, p. 184
Yonezawa, M.	Associate '25	Feb. 9, 1940	Associate	Apr. 1941, p. 184
Young, G. C.	Associate '37	June 23, 1940	Associate	Aug. 1940, p. 346

aged to keep in close touch with chairmen of Section membership committees within their respective Districts, and to give them such advice and assistance as may be appropriate.

The results of membership committee work of the Institute are indicated by tables III to VIII, inclusive.

Table III shows the total number of members as of April 30, 1941, to be 17,886, as compared with 17,213 at the end of the corresponding period of 1940. This is a net increase of 673 members.

The results of membership committee work are better indicated by table IV, which shows that 1,898 new applications were received during the year ending April 30, 1941, as compared with 1,829 in the corresponding period preceding, and considerably lower figures for the three years preceding 1940.

The figures on Enrolled Students are shown in tables IV and V. It will be noted that there was a falling off in 1941 in applications from students for election to the Associate grade. This was probably influenced by the induction of a large number of young men into military service during the year and the uncertainty which prevailing conditions imposed upon employment.

Tables VI and VII show data as to reinstatements and payment of dues, and table VIII shows the total membership of the Institute for each year since it was founded.

The committee wishes to express its appreciation of the time and effort devoted to membership work by the members of Section membership committees, many of whom have been working under pressure in their occupations. It is also grateful for the cooperation of the Branch counselors who have promoted student enrollment and written to students after their departure, advising them to become members of the Institute. Finally the committee wishes to thank the Institute members for their help and the fine response to the broadcast circular soliciting their aid in suggesting the names of desirable prospects for membership.

Deaths. The deaths of 80 members reported during the year are listed in table IX.

BOARD OF EXAMINERS

The board of examiners held 11 meetings during the past year, averaging about two and one-half hours each, and considered 3,086 cases, divided as shown in table X.

In addition to the routine consideration of the admission and transfer applications referred to in the preceding paragraph, the board during the past two years has engaged in thorough discussion of the practicability of some procedure which would permit the rendering of informal advance opinions on the eligibility of prospective applicants for admission and transfer to the grades of Fellow and Member.

Increasing sentiment for change in procedure led to a most constructive discussion at the summer convention in June 1940 After the chairman of the board of examiners had explained to the conference of officers, delegates, and members the problems confronting the examiners, the conference went on record for an invitational procedure, and recommended that the board of directors direct a study to this end.

As a result of this request from the board of directors, a subcommittee under Vice-Chairman H. S. Warren was appointed. This committee developed a plan which seems to offer a solution of the difficulties which previously led the examiners to oppose strongly the frequently recurring request from Section membership committees that the examiners render advance opinions on eligibility. The plan has been approved by the board of directors, and it now merely remains to arrange the necessary forms for putting it into regular operation.

The new procedure, which might be designated as the "invitational transfer method," applies only to Fellow grade. It will not require any change in the constitution, and will be supplementary to the present "Proposal Method" for advancement to Fellow

Table X. Applications for Admission and Transfer

Applications for Admission		
Recommended for grade of Associate	534	
Re-elected to the grade of Associate	78	
Not recommended	8	620
Recommended for grade of Member	116	
Re-elected to the grade of Member	22	
Not recommended	36	174
Re-elected to the grade of Fellow	2	2
Applications for Transfer		
Recommended for grade of Member	174	
Not recommended	14	188
Recommended for grade of Fellow	39	
Not recommended	0	39
Students		
Recommended for enrollment as Students		2,063
Total		3,086

In brief, it provides a means whereby a group of Members and Fellows desiring to promote the advancement to Fellow status of another individual may propose him over their signatures as at present, one of the Fellows designating himself as the official sponsor for such transfer. The sponsor will be required to obtain and to furnish to the board of examiners, over his signature, a fully detailed professional record of the prospect, together with the names of the required number of Fellows who will be willing to act as references. The examiners will then submit to these references the regular reference forms and obtain their confidential replies. Any correspondence with regard to references or additional details of record will be solely between the examiners and the official sponsor. The examiners will then pass unofficially on the question of eligibility and communicate their action to the official sponsor, who will approach the proposed Fellow and will then obtain his consent to the transfer action and his signature on the application. With the signed application in hand, the examiners will then take formal action. The remaining steps as to posting, and so on, will be unchanged from the present procedure.

It is hoped that the new procedure will meet the expressed wishes of the membership and the board of directors, and the examiners will strive to make it work, while at the same time discharging their heavy responsibility of upholding the high standards set for such recognition of outstanding achievement in the profession.

The board of examiners now recommends to the board of directors that a statement be prepared and generally broadcast to the Institute membership clearly outlining the new procedure available for advancement to Fellow through the "invitational method".

All questions with regard to change in procedure for transfer to Member grade were laid over for further careful study in the light of prospective experience with the new procedure for Fellows. Rejections of transfer applications to Member grade have tended to run high (over 25 per cent). As also pointed out last year, this apparently is due in part to a failure to appreciate the technical requirements prescribed by the constitution, somewhat to a tendency to aspire to Member grade merely because the 27-year minimum age limit has been reached, and slightly to the increase of dues (to parity with those of Member grade) at the end of the 6-year period of Associate membership.

HEADQUARTERS COMMITTEE

It seemed to the committee that conditions at the headquarters of the Institute were such that a considerable amount of renovation work should be carried out during the year. The finance committee, therefore, brought the matter before the board of directors at the meeting on January 30, 1941, and authority was given to proceed with the work as proposed, up to the limit of certain funds in the depreciation accounts which were immediately available for the purpose.

As of this writing the work is nearly completed. The committee realizes that tastes vary so greatly concerning furniture and decorations that no unanimity of opinion can be expected regarding changes of this kind. It hopes, however, that the membership in general will consider the results to represent a satisfactory handling of the situation within the limits of the available funds.

The committee has been especially fortunate in being able to draw on the professional experience and judgment of R. H. Hose of the Bell Telephone Laboratories. He proposed the general plan of redecoration, prepared the sketches which were submitted to the board in January, and has co-operated closely in carrying out all phases of the work. The committee is greatly indebted for a large amount of his time and for his continuous interest and guidance.

COMMITTEE ON PLANNING AND CO-ORDINATION

The committee has had to hold only one meeting during the year, its predecessor for the preceding administrative year having completely cleared a rather extensive accumulated docket and rendered comprehensive reports to the board of directors during last year.

In addition to the usual recommendations to the board of directors with respect to the schedule of meetings for the calendar year 1942, the committee considered and advised the board concerning a proposed new technical committee, dues which Members for Life continue to pay, proposed review of past applications of electricity in warfare, and the use of United States standards in South America.

COMMITTEE ON CONSTITUTION AND BYLAWS

There were several amendments to the bylaws. One extended the period of time in which Enrolled Students may apply for admission to Associate grade without payment of entrance fee, particularly to affect students graduating in the January class, or at times other than the usual June commencement. A section was added to the bylaws covering the Charles LeGeyt Fortescue Fellowship committee; also a section covering the committee on research, in view of its change in status from a technical committee to a general committee.

Minor revisions were made with regard to the listing of committees.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT

The committee has carried on some correspondence, but no matters have required immediate action. The chairman is also chairman of the joint committee on principles of ethics, now sponsored by the Engineers Council for Professional Development, which expects to have a report ready for presentation in the fall.

COMMITTEE ON SAFETY

It was reported last year that a subcommittee had been appointed to develop further contacts with the colleges and Student Branches on safety. This effort resulted in a bulletin entitled "Suggestions for Meetings on Safety", which was mailed to the chairman of each Student Branch and to each Student Branch counselor on September 23, 1940. The purpose of the bulletin was to urge the Student Branches to hold one or more meetings on safety during the school year, and it gave them numerous suggestions about organizing such meetings, sources of speakers, and references to safety codes and other publications on the subject. Reports indicate that numerous Student Branches have found this bulletin useful, and it is intended to mail a similar bulletin to them again next September.

A letter was sent also to the Sections of the Institute urging upon them the importance of greater attention to safety and suggesting that at least one meeting be held on this subject.

The committee has asked the technical program committee to call to the attention of each of the national technical committees the importance of greater attention to safeguarding life and property from electrical hazards. In periods of high industrial activity, there is always a tendency toward an increase in the accident rate resulting in an increase in lost time and damaged material.

All these steps have been taken as parts of a co-ordinated effort to aid the national defense preparations by conservation of man power and materials through increased safety measures.

During the year, the committee sponsored two papers which were presented before conventions of the Institute. One was a paper by W. B. Kouwenhoven, D. R. Hooker, and O. R. Langworthy, entitled "A Comparison of the Relative Efficiency of the Schafer and Pole-Top Methods of Artificial Respiration" which was presented at the Middle Eastern District meeting in Cincinnati, Ohio. This is a valuable contribution to the fund of knowledge on this important subject. The other was a paper by C. F. Dalziel, J. B. Lagen, and J. L. Thurston, entitled "Electric Shock", presented at the 1941 winter convention. It presents valuable data regarding the let-go values of currents which human beings can withstand. The committee believes there is need for further data of this kind, not only with respect to the let-go currents human beings can withstand, but also as to the susceptibilities of animals to electric currents.

The committee wishes to stress the importance of proper maintenance of electrical apparatus and machinery as an important factor in continued safe operation. During periods of high production when plants are being operated long hours under heavy loads, increased attention to maintenance is necessary to avoid injuries, lost time, lost production, and damaged materials caused by avoidable failures.

Active attention to these and many other problems is planned for the coming year.

COMMITTEE ON RESEARCH

The change in status of the committee on research from that of a technical committee to that of a general committee of the Institute was authorized by the board of directors at its meeting on May 24, 1940, and appropriate changes in the bylaws, section 84-A, were adopted by the board on January 30, 1941. This change has relieved the committee of certain duties that it previously discharged in connection with the review of papers.

The principal activity has been that of studying the program of Engineering Foundation research projects sponsored by the Institute. For the purpose of developing more clearly their relation to the broad problems of electrical engineering, two projects have received particular attention. These are a research on the stability of impregnated-paper insulation, project 66, which has been under way for some years at the Johns Hopkins University, under the immediate direction of Doctor J. B. Whitehead. Another is a research on insulating oils and cable saturants, project 74, under way at the Massachusetts Institute of Technology, under the immediate supervision of Professor J. C. Balsbaugh. Each of these projects is supervised by an advisory committee which meets several times a year, considers in detail the status of the project, and prepares recommendations as to future programs.

Recommendations and reports of these advisory committees have in turn been considered by the committee on research before submitting them to the board of directors for consideration. The committee has not to date undertaken a review of the welding research program of Engineering Foundation jointly sponsored by the Institute and the American Welding Society. This has not been from lack of interest or sympathy but because it was felt that the direction of this activity is being ably handled by existing committees. It is suggested, however, that succeeding committees on research consider this matter in order to insure effective integration of the Institute's research activities.

Although it is still too early to judge the full value of the change in status of the committee, it is believed that experience to date has demonstrated the desirability of the change. Should the general national situation become such as to lead to special calls on the Institute for activities in the field of research, the value of the committee will be still further apparent.

Standards

STANDARDS COMMITTEE

During the past year there has been a noticeable expansion of standards activity. This probably is due to increased industrial activity brought about by the national defense program. The American Standards Association has taken formal action urging all possible speed in standards development as an effective aid in that program. In line with this policy, it may be pointed out that proposed revisions of many AIEE standards have recently become available. Among these may be mentioned No. 4, "Measurement of Test Voltages in Dielectric Tests"; No. 21, "Apparatus Bushings"; No. 22, "Air Switches and Bus Supports"; No. 24, "Protector Tubes"; No. 27*A*, "Switchgear Assemblies"; No. 25, "Fuses Above 600 Volts"; No. 28, "Lightning Arresters"; No. 41*A*, "Insulator Tests"; and No. 45, "Recommended Practise for Electrical Installations on Shipboard". The call for this last standard, No. 45, is growing rapidly and the demand for it probably will become even greater, as compliance with its requirements is now a part of nearly all shipbuilding specifications. In addition to the preceding strictly AIEE activities, sectional committees working under ASA procedure have issued, or are about to offer, several standards and proposed standards. One on "A-C Power Switchgear" and one on "Transformers, Regulators, and Reactors" are now available, and revisions of all the various letter and graphical symbols standards are practically completed.

The sectional committee on definitions of electrical terms is rapidly bringing its work to a point where the final step necessary to obtain approval as an American Standard can be taken. The appointment of a new chairman, C. H. Sanderson, to replace Doctor A. E. Kennelly, deceased, has been made, and the addition of a man to the AIEE staff to devote the major part of his time to this work has greatly expedited the compilation of the immense amount of data involved in the completion of this report.

In the test-code field, activity has also increased. A revised edition of the "D-C Test Code" is under way, and the development of a code for electrical measurements is being considered. A test code is also offered as part of the proposed pamphlet on "Bushings". A specification for wet tests is about to be published. The Institute has appointed a representative to serve on a sectional committee on "Code for Safety in Quarry Operations".

Following out Past-Chairman Hellmund's plan for a more closely knit organization aimed to bring about close co-operation among various standardizing groups and proper co-ordination of the results of their work, a seventh co-ordinating committee has been appointed, on conduction in vacuum, gases, liquids, and solids. Further development of the "Standards Manual" is also under way. It is expected this manual will promote a closer understanding of available standardizing machinery and the interrelationships of the various committees engaged in that work.

Another question of considerable import coming up for discussion during the year was the establishment of a proper policy with regard to withdrawal of standards when proposed revisions become available. It was finally agreed that, in order to preclude the possibility of arguments between manufacturers and customers on adherence to existing standard practice, a standard should remain in force until actually replaced by a formally accepted revision.

Under ASA procedure, it is customary to classify the membership of sectional committees according to company affiliation. However, it has always been the Institute's policy to consider that its committee appointees are representative of independent interests and that they would, whenever practical, render decisions from that viewpoint. The ASA therefore was formally requested in future to classify Institute appointees as independent interests unless advised otherwise.

In view of the present American policy to strive for closer relationships between the United States and South and Central American countries, steps were taken to ascertain the feasibility of translating into Spanish and Portuguese such United States electrical standards as would have the greatest application in the development of trade in the electrical field. This work, if carried through, probably will be in co-operation with the United States Department of Commerce.

UNITED STATES NATIONAL COMMITTEE OF THE IEC

At its annual meeting in December 1940, the United States National Committee of the International Electrotechnical Commission re-elected its officers: E. C. Crittenden, president, L. F. Adams and H. S. Osborne, vice-presidents. Doctor C. H. Sharp continues as honorary president.

Due to the international situation, the work of the IEC is practically in a state of suspension. The central office of the commission, however, has not been disbanded, so that as soon as circumstances permit it will be possible to resume activities. The United States National Committee, as well, is keeping its organization intact, and will continue to hold an annual meeting.

At the annual meeting of the USNC, there was a full discussion of the desirability and possibility of the USNC taking the lead in developing international electrical standardization work between the countries of North and South America. The result of this discussion was the appointment of a special committee under the chairmanship of President Crittenden, of the USNC, with L. F. Adams, H. S. Osborne, and Frank Thornton, Jr., as members, to explore the whole situation and to make contacts with the Pan-American Union, proper officers and departments of the Federal Government, technical societies and trade associations, and others, and to make recommendations to the USNC on the whole subject. This action of the USNC was readily concurred in by the ASA. The AIEE committee on planning and co-ordination has also appointed this same group, with the addition of D. M. Simmons, as its committee to investigate the same subject.

Technical Committees

COMMITTEE ON AIR TRANSPORTATION

The establishment of this new technical committee was authorized by the board of directors on August 2, 1940, and the organization was completed in October. At the first meeting on November 15, the committee discussed the scope of its activities, recommended co-operation with governmental agencies in defense problems, and began the study of papers for the winter convention.

The committee has made special efforts to secure an adequate number of papers of high quality for presentation at national conventions and District meetings, but has had great difficulty on account of the close relationship of developments in its scope of activities to national defense, with the resulting restrictions on dissemination of information. It has instigated efforts to increase the membership in the Institute of qualified persons in the aircraft and associated fields.

On recommendation of the committee,

it was authorized by the board of directors to offer its services to governmental agencies in connection with the application of electrical equipment to aircraft. Co-operation with several agencies has been established.

COMMITTEE ON AUTOMATIC STATIONS

The committee prepared a bibliography for the period 1932–40, inclusive, containing approximately 800 references on supervisory and remote control, telemeters and telemetry, automatic and remote control switchgear, automatic features of generating stations using fuels, automatic boiler and combustion control, automatic hydroelectric plants, automatic substations (installations).

Several members of the committee, as members of the joint subcommittee on telemetering and supervisory control, collaborated in the preparation of a report on the latter subject (see report of committee on instruments and measurements).

The committee approved proposed standards for nominal voltages below 100.

The committee sponsored the paper on "Synchronizing Transients and Synchronizers for Large Machines" by R. D. Evans, F. H. Gulliciksen and C. B. Myhre, published in the 1940 TRANSACTIONS, pages 965–73.

In co-operation with the relay subcommittee of the protective devices committee, the committee on automatic stations has sent out a number of questionnaires covering the use of pilot conductors in supervisory control, telemetering, and calling and signalling systems. These data will be collected, with similar data pertaining to protective relays.

COMMITTEE ON BASIC SCIENCES

Papers reviewed and recommended by the committee included 3 for the 1940 summer convention, 7 for the 1941 winter convention, and one for the North Eastern District meeting in Rochester, N. Y. The committee also held a technical conference at the summer convention, and two such conferences and a meeting of the committee at the winter convention.

Considerable progress was made by the subcommittee on definitions of electrical terms.

The committee has approved 4 papers for a joint session with the subcommittee on electronics at the 1941 summer convention.

COMMITTEE ON COMMUNICATION

The committee on communication held three meetings during the year. Much additional business was conducted by correspondence. The committee arranged communication programs at the summer and Pacific Coast conventions, in 1940, and the 1941 winter convention, and assisted in obtaining material for the Middle Eastern District meeting in Cincinnati. The 15 papers sponsored by the committee at these meetings dealt with many subjects—telegraphy, telephony, radio, electronics, television—and nearly every aspect of the communication art and science was represented to some extent in these papers. Programs have also been arranged for the 1941 summer and Pacific Coast conventions.

COMMITTEE ON DOMESTIC AND COMMERCIAL APPLICATIONS

A paper by L. C. Packer, Associate AIEE, entitled "Design Factors Involved in the Design of Domestic Motor Appliances", was presented at the Middle Eastern District meeting, Cincinnati, Ohio, October 9–11, 1940. A paper by W. J. Russell is now being reviewed, and a third by W. H. Delancey has been submitted, both the latter being intended for presentation at the summer convention in Toronto, Canada, in June 1941. Two or three other papers have been promised, but have not yet been produced.

A conference period has been arranged for at the summer convention and appropriate arrangements have been made for prepared discussions to open this conference.

No standardization activities have been undertaken by this committee during the fiscal year. The committee has indicated that it will not require any budget appropriation for the ensuing fiscal year.

COMMITTEE ON EDUCATION

The committee held a meeting at the 1941 winter convention, and is planning to hold a conference at the summer convention.

Three subcommittees were continued from the previous year. Replies to the questionnaire of the subcommittee on student guidance were received from 58 Sections. The subcommittee has transmitted definite suggestions to the Sections interested, and expects to report on its activities at the summer convention conference of officers, delegates, and members.

COMMITTEE ON ELECTRIC WELDING

The activities of the committee on electric welding have been largely those of a subcommittee on power supply for welding operations. This subcommittee has recommended that the National Electrical Code be amended to cover specific requirements for resistance-welder installations. At present, the code makes no mention of resistance welders, and it becomes necessary for the various local authorities to make their own interpretations as they think may apply to resistance welders. Resistance welders are far different from ordinary power and light load, and the necessary wiring, fusing, and service facilities must be provided on a somewhat different basis. The subcommittee prepared suggested paragraphs covering conductor sizes for branch circuits and feeders supplying resistance welder loads which were transmitted by the secretary of the standards committee to the chairman of the sectional committee on National Electrical Code.

The subcommittee has prepared purchase inquiry forms and manufacturers' data sheets which should prove of mutual aid to both the users and the manufacturers in reaching a common understanding as to just what type and size of welding machine is needed for a given job, as well as furnish complete power supply data to the users' electrical department and the local power company. The forms cover both machine mechanical data and power-supply data. The subcommittee is concerned particularly with the sections covering power-supply data, and thinks that by proper use of these forms the providing of an adequate power supply for any welding operations will be greatly facilitated. While the forms covering the mechanical data are not the direct concern of this subcommittee, it is felt that they should be included with those covering the power-supply data. Copies of the purchase inquiry forms and manufacturers data sheets have been submitted to the secretary of the Resistance Welder Manufacturers Association, and are being distributed to its entire membership for their suggestions.

The subcommittee, during the past two years, has spent considerable time in the preparation of a report on power supply for resistance welding machines, and has completed Section III covering "Factory Wiring for Resistance Welders". Section I, "Guide to Good Electrical Performance of Resistance Welding Machines" and section II, "Resistance-Welder Installations" have been printed and made available for distribution. Section III was presented at the North Eastern District meeting, April 30–May 2, and published in the 1941 TRANSACTIONS (May section) pages 185–92.

COMMITTEE ON ELECTRICAL MACHINERY

The subcommittee on synchronous machinery has been extensively engaged in work on revision of the "Test Code for Synchronous Machines". Substantial progress has been made, and it is expected that the revision will be ready for submission to the standards committee during the ensuing fiscal year.

The subcommittee on transformers prepared a very comprehensive report on the protection of power transformers against lightning surges, which was presented at the winter convention. This report is a result of several years of study by the subcommittee, and furnishes information as to the degrees of protection possible and the various methods in common use. The subcommittee has also given careful study to the proposed ASA Standards, and through membership on the ASA sectional committee is suggesting recommendations for changes and improvements. The subcommittee is also studying proposed changes in the test code section of the ASA Standards.

The d-c subcommittee has revised the "Test Code for D-C Machinery" following suggestions of the standards committee and incorporated the "Test Code for Fractional Horsepower D-C Motors." The test code has been submitted to the standards committee with a recommendation that it be published for trial use.

The subcommittee on test codes for single-phase motors has prepared a final draft of the "Test Code for Single-Phase Motors" which is practically in final form. It is expected that this test code will be submitted to the standards committee with a recommendation for publication for trial purposes during May 1941.

During the year, a co-ordinating committee consisting of the chairmen of various other subcommittees was organized to aid in co-ordinating work of the various test codes. Professor H. N. Walker of the committee on instruments and measurements was added to this subcommittee as a liaison member from that committee.

One session at the 1940 summer convention was sponsored by the committee on electrical machinery, in which 4 papers were presented. At this convention, a technical conference was devoted to test codes. At the Middle Eastern District meeting held in Cincinnati in October 1940, 1 session

was devoted to electrical machinery, at which 5 papers were presented. At the 1940 Pacific Coast convention in Los Angeles, Calif., in August 1940, 1 session was devoted to electrical machinery, at which 4 papers were presented. At the 1941 winter convention, 2 sessions were sponsored by the committee, at which 9 papers were presented. At the North Eastern District meeting in Rochester, N. Y., April 30 to May 2, several papers recommended for presentation by the committee were presented, although under the auspices of other committees. At the 1941 summer convention in Toronto, it is planned to have 1 session sponsored by the committee at which 4 or 5 papers are planned for presentation. Some other papers have been reviewed and are available.

COMMITTEE ON ELECTROCHEMISTRY AND ELECTROMETALLURGY

With the approval of the board of directors, the committee arranged for a joint afternoon technical session and a joint evening technical conference with the American Society for Metals on the last day of the 1941 winter convention. Two AIEE papers were presented in the afternoon, and two addresses were given by members of the ASM in the evening.

A subcommittee for the investigation of voltage transients in the operation of arc furnaces had been organized in March 1940, and the first meeting was held in October 1940. At this meeting, it was decided to enlarge the subcommittee considerably by the addition of advisory members, including representatives from the furnace manufacturers. Plans were also made for extensive field investigations.

A progress report was presented at the second meeting of the subcommittee, held at the winter convention. It is expected that a partial report of findings of the subcommittee will be available in about 6 months and a complete report in 12 months. The investigation so far has covered conditions under which voltage transients are produced, their magnitude, probability, and methods of prevention.

A meeting of the committee was held at the winter convention. It was decided to arrange for a joint session with the Association of Iron and Steel Engineers for May 27, 1941. The program for this meeting is already in final shape. It will consist of a special joint meeting of the Cleveland and Pittsburgh Sections of the AIEE and the AISE, and will be sponsored by the committee on electrochemistry and electrometallurgy.

Plans are under way for a report on progress in the field of electrochemistry and electrometallurgy, to be available in the spring of 1942.

COMMITTEE ON INSTRUMENTS AND MEASUREMENTS

During the year, the activities of the committee consisted primarily of the review of papers, the arrangements for their presentation at conventions, the sponsorship of a technical conference, the preparation of reports on the progress of the art in the field of instruments and measurements, and the revision of test codes, definitions, and standards. Seventeen papers have been submitted in whole or synopsis form for review by the committee.

Technical sessions were held at the summer and winter conventions, and a technical conference on dielectric measurements in the field was held at the summer convention. Seven prepared reports were presented at this conference, and between 50 and 60 members were present.

A report on "Telemetering, Supervisory Control, and Associated Circuits" was completed by a joint subcommittee of the committees on instruments and measurements and on automatic stations. This report contains a classification of 53 of the numerous types of telemetering and supervisory control equipment now manufactured, a description of each type, and a comparative tabulation of the characteristics of all. The report has been approved by both technical committees and sent to the publication committee for publication in pamphlet form. It is hoped that the report may be the basis for a standard on its field in the future.

A report on "Progress in the Art of Metering Electrical Energy" is nearing completion. No previous report on the subject having been written by the Institute, the scope of this report is wider than that of others, and the development of electrical-energy measurement is traced from its inception down to the present time. The report is the result of collaboration by authorities in various fields—educational, manufacturing, operating, regulatory, and scientific. It should be completed before the 1941 summer convention, and it is hoped that it will be published both in ELECTRICAL ENGINEERING and in pamphlet form.

A report entitled "Wave Form in Dielectric Power Factor Measurements", on the methods of specifying the voltage wave form of the power source employed in measurements of the power factor of dielectrics, was completed and published in ELECTRICAL ENGINEERING, June 1940, page 255.

A subcommittee has been studying the test codes prepared by the committee on electrical machinery, and suggestions for revision of certain parts of the codes pertaining to instruments and measurements have been passed on to the committee on electrical machinery. As a result of this work, a representative of the committee on instruments and measurements has been appointed to the subcommittee of the committee on electrical machinery that is preparing the test codes, and a subcommittee of the committee on instruments and measurements has been set up to prepare a master test code on resistance measurements. Work on a master test code on temperature measurements has been started.

The definition of the galvanometer has been modified, and the name "phase-shifting transformer" approved to describe the miniature transformer used to adapt wattmeters and watt-hour meters to reactive power measurement. A subcommittee on electrical definitions is attempting to coordinate definitions in the *C42* report, the "Electrical Metermen's Handbook," and the "Code for Electricity Meters."

The definitions of the terms "instrument" and "meter" have been reconsidered and modified to broaden the scope of the latter.

A new subcommittee on accuracy classification of instruments and instrument standards has been set up recently to attempt to formulate improved methods of stating the performance or accuracy of indicating instruments. This subcommittee is the newest of 11 now active. As a means of coordination there are representatives of the committee on instruments and measurements on the joint subcommittee on electronics, the relay subcommittee of the committee on protective devices, the test-code subcommittee of the committee on electrical machinery, and 3 subcommittees of the standards committee.

A report covering most of the more important work of the committee for the past few years was given by the secretary at the winter convention, and was published in ELECTRICAL ENGINEERING, March 1941, pages 133–4.

COMMITTEE ON LAND TRANSPORTATION

Three meetings were held during the past fiscal year: one at the summer convention, Swampscott, Mass., one in Chicago, Ill., in October, and the last at the winter convention, in Philadelphia, Pa.

The name of this committee was changed from committee on transportation to committee on land transportation, at the time the board of directors established a committee on air transportation.

The committee has four subcommittees, which enable it to cover adequately the land-transportation field in which practically all the papers must be solicited. Standardization along the lines of the PCC car makes it almost impossible to bring forth new papers in the light-traction field. However, at the winter convention, in January, a paper on "The Electro Gear—A New Electromechanical Transmission", by Doctor Ernst Weber, aroused a tremendous amount of interest in the field of urban transportation. Considerable space was devoted by the various transportation publications to comments on Doctor Weber's paper.

COMMITTEE ON MARINE TRANSPORTATION

In July 1940, AIEE Standard No. 45, "Recommended Practise for Electrical Installations on Shipboard", was reprinted to include a complete revision, the detail work for which was accomplished last year.

Due to the pressure of work incident to the current large shipbuilding program, there has been little activity this year, although at our committee meeting on January 10, 1941, all business at hand was transacted, including future changes in Standard No. 45 to be handled by addenda sheets.

The principal item of business of this committee is to keep Standard No. 45 up to date for use by shipbuilding and other organizations. However, it is hoped that when time becomes available, some definite activity on standards for equipment may be undertaken.

COMMITTEE ON POWER GENERATION

Eleven technical papers were presented under the sponsorship of the committee: summer convention, 2; Middle Eastern District meeting, Cincinnati, 1; and winter convention, 8.

A conference, similar to that at the 1940 summer convention in Swampscott, Mass., was held at the Pacific Coast convention, at which the same and additional material was presented.

More than the usual amount of interest was shown in the session of the committee

at the 1941 winter convention, the attendance for both sessions being exceptionally large. The committee has given most of its attention during the past year to the study and discussion of subjects relating to governor design and operation, load fluctuations, system stability, and associated phenomena.

The studies which have been carried on during 1940 are being continued into the 1941 summer convention in Toronto by conference studies. Material is also being prepared for a general discussion in Toronto covering preparedness in its relation to power generation.

Steps are being taken toward the formation of a joint committee with The American Society of Mechanical Engineers on the standardization of the design of the governor and its associated equipment.

COMMITTEE ON POWER TRANSMISSION AND DISTRIBUTION

The committee held two meetings during the year. In addition to transaction of routine business at these meetings, there were general engineering discussions of a number of matters relating to transmission and distribution. This review of engineering development is becoming an extremely valuable part of the committee activity.

The committee is now operating on the basis of the new organization, under which there are four subcommittees: transmission, distribution, stations, and general system.

During the year, Standard No. 41, Insulator Tests, was approved for printing as a tentative standard. It is expected that, after this tentative standard has been in use one year, a decision will be reached with respect to printing as an ASA standard. The committee is now engaged in the task of preparing a revised report on grounding standards.

The committee sponsored 1 technical session at the summer convention, and 2 technical sessions at the winter convention, involving the presentation of 11 papers, and in addition there were 7 papers presented in other sessions jointly sponsored. The committee also co-operated in arranging for the presentation of technical papers at District meetings during the year.

COMMITTEE ON PRODUCTION AND APPLICATION OF LIGHT

The committee has continued during this fiscal year to keep members of the Institute informed on the latest developments in illuminating engineering, principally through the sponsorship of conferences at District and national meetings and by obtaining papers from qualified authors on illumination subjects for publication in ELECTRICAL ENGINEERING. All of these activities have been intensified this year, and plans are now under way to further extend them, especially in those lighting fields which are vital to national defense.

The committee held a protective lighting conference at the Middle Eastern District meeting, Cincinnati, Ohio, October 10, 1940, and a fluorescent lighting conference at the winter convention, Philadelphia, Pa., January 29, 1941. A complete report on each of these conferences appeared in ELECTRICAL ENGINEERING, and the prepared discussions at the fluorescent lighting conference are scheduled for publication in the June 1941 issue of ELECTRICAL ENGINEERING, because of their timely interest to the Institute membership.

A conference on protective lighting is now under consideration for the summer convention in June 1941. Prominent speakers from Canada and the United States will be asked to prepare discussions on this subject which is vital to the defense of each country.

In addition to reviewing all papers on the subject of lighting which are presented for consideration by the technical program committee, this committee also selects timely lighting subjects and encourages competent authors to prepare papers for ELECTRICAL ENGINEERING.

The committee met only once during the year, since membership is rather widely scattered, and activities can well be carried on by mail after plans have been settled for the year.

COMMITTEE ON PROTECTIVE DEVICES

During the past year, 15 new members were added to the committee, and 10 retired. Representation was added from the Southern, Pacific, and North West Districts, with a corresponding reduction in certain other Districts. The representation from the various divisions of work within the committee's scope was kept as broad as possible.

The committee activities have been divided so that each member has some assignment, and excellent co-operation and valuable assistance have been given by the subcommittee chairmen and their various individual members. The four main subcommittees are: circuit breakers, switches, and fuses, fault-current limiting devices, lightning arresters, and relays.

The subcommittee on circuit breakers, switches, and fuses has been active on a number of important projects including the review of Standard No. 19, "Circuit Breakers", to incorporate air circuit breakers and new insulation test levels. Proposed Standard No. 25, "Fuses" has been studied to incorporate the new insulation test levels. Studies have been made of voltage recovery rates, oil for impulse testing, and short-circuit calculation practices for the application of interrupting devices. Reports on the latter two subjects have been completed, and are scheduled for presentation at the summer convention. The recent adoption of basic insulating levels calls for a reconsideration of voltage tests on certain electrical equipment. The present test values for protective apparatus, especially in the lower voltage classes, is being given study, and in some cases may require modification.

Standard No. 22, "Air Switches and Bus Supports" was printed in June 1940, and issued for one year's trial use. Standard No. 24, "Protector Tubes" was printed and issued in August 1940, for one year's trial. Standard No. 27, "Enclosed Switchgear" has been completed, approved by the AIEE standards committee, and soon will be printed and distributed for one year's trial use as a revised standard.

A standard for neutral grounding devices has been completed and submitted to the standards committee for approval and publication as a proposed standard. The subcommittee on fault-current limiting devices is co-operating with other technical committees in the review of the "Grounding Practices Report".

Standard No. 28, "Lightning Arresters", has been revised, approved, and submitted to the standards committee for adoption. This material has been passed on to ASA sectional committee *C-62* for consideration as a revised ASA standard.

Additional data have been obtained, particularly at high values of discharge current, concerning the performance characteristics of line-type lightning arresters rated 20 kv to 73 kv inclusive, and assembled in the form of a report for presentation at a forthcoming meeting. Work is in progress toward the development of a standard for distribution type protector tubes.

The subcommittee on relays has carried on a number of important projects including the standardization of potential devices and instrument transformers; studies of pilot wire relaying experience; sensitive ground protection; automatic recording devices, and out-of-step protection. A compilation is being prepared to show the desired scope of manufacturers' catalog information. A bibliography of relay literature was prepared last year and this is now in process of being printed and made available to the industry.

The special representatives on other committees have co-operated in the furtherment of insulation co-ordination and the application of new developments in connection with contact surfaces.

The various subcommittees collaborated last year in the preparation of material for use as a report "Progress in the Art". This is now being brought up to date, and arrangements have been made for its publication in ELECTRICAL ENGINEERING, in three sections entitled "Circuit Interrupting Devices", "Relaying and Fault-Current Limiting Devices", and "Lightning Protection and Miscellaneous".

The committee has sponsored technical papers as follows: 1940 summer convention, 6; Middle Eastern District meeting, Cincinnati, 1; Pacific Coast convention, Los Angeles, 4; winter convention, 4 on circuit breakers, 5 on relays and other subjects, and 5 on transmission and protective-devices subjects (joint with committee on power transmission and distribution); and North Eastern District meeting, Rochester, 1. A number of additional papers are available for subsequent meetings, and 10 will be presented at the 1941 summer convention.

The committee held four meetings and a fifth is scheduled for May. These meetings have been well attended, and the discussions have consisted largely of committee activities, action regarding proposed standards, basic insulation levels, temperature rise and ambient temperatures for enclosed switchgear, presentation of subcommittee reports, and consideration of papers for future programs.

It is expected that the future work of the committee will follow along similar lines, completing the several standards which are now in preparation on circuit breakers, fuses, potential devices, instrument transformers, protector tubes, and so on. In view of the great interest being shown in this work as evidenced by attendance at the technical sessions and at the committee meetings, and the large number

of papers proposed, it would appear that the work is being carried forward along useful and progressive lines.

Awards

COMMITTEE ON AWARD OF INSTITUTE PRIZES

Four national and ten District prizes were awarded for papers presented during the calendar year 1940 and for the student papers presented during the academic year ending June 30, 1940.

The committee considered a large number of eligible papers which were of a high order, and, in determining the awards for the national best paper prizes and initial paper prize, it had the benefit of the gradings and recommendations of the technical committees, which had reviewed the papers. In addition to the national paper prize awards, three other papers were given honorable mention.

The pamphlet "National and District Prizes" has been revised, and a new edition of January 1941 issued. The principal changes establish a new basis of grading for Branch and graduate paper prizes, and empower the District executive committees to fix the dates of closure and of award of the District prize for Branch paper and the District prize for graduate paper. The new basis of grading recognizes that the objective of student papers differs from that of adult papers, and permits the placing of greater emphasis on the written presentation and on the exercise of engineering thinking than on technical value. These changes were made in co-operation with the committee on Student Branches and the recommendations of the conference of Student Branch counselors held during the summer convention, in Swampscott, Mass.

EDISON MEDAL

The Edison Medal, which is awarded by a committee composed of 24 members of the Institute, was awarded for 1940, to George Ashley Campbell, "in recognition of his distinction as scientist and inventor and for his outstanding original contributions to the theory and application of electric circuits and apparatus", and was presented on January 29, 1941, during the winter convention. The medal may be awarded annually for "meritorious achievement in electrical science, electrical engineering, or the electrical arts".

LAMME MEDAL

The Lamme Medal committee awarded the medal for 1940 to Comfort A. Adams, consulting engineer, Edward G. Budd Manufacturing Company, "for his contributions to the theory and design of a-c machinery and his work in the field of electric welding". Arrangements are being made for the presentation of the medal at the summer convention in Toronto, Ont., Canada, June 16–20, 1941. The medal may be awarded annually to a member of the AIEE "who has shown meritorious achievement in the development of electrical apparatus or machinery".

COMMITTEE ON AWARD OF COLUMBIA UNIVERSITY SCHOLARSHIPS

Due to the very large demand for young engineers by the industries there was not as much interest displayed in the scholarship as in previous years, and the few applications received were from students who either could not afford to undertake the expense of living in New York City, even with their tuition covered by the scholarship, or did not meet the specifications for previous work. Therefore, the scholarship was not awarded for this academic year.

In view of the very uncertain conditions in the coming academic year, and the fact that the great majority of engineering graduates are being taken by the industries and the selective service, the University authorities decided not to offer the scholarship during the academic year 1941–42. This is the second time in the many years since the scholarship was established that no award has been made.

CHARLES LE GEYT FORTESCUE FELLOWSHIP COMMITTEE

The committee, at its meeting in March, decided that no award would be made for the scholastic year 1941–42, because of the national emergency and the limited number of candidates making application for the fellowship. The demands for young men in industry and in the various branches of military service apparently have taken many who might otherwise have applied for the fellowship. It was also thought that after the present emergency is over the accumulated funds may be more useful in helping deserving young men readjust themselves to normal industrial life.

JOHN FRITZ MEDAL

The John Fritz Medal board of award, composed of representatives of the national societies of civil, mining and metallurgical, mechanical, and electrical engineers, awarded the 37th medal (for 1941) to Ralph Budd, president, Chicago, Burlington, and Quincy Railroad, for "improvement of railroad tracks and service, especially the introduction of lightweight streamlined trains".

HOOVER MEDAL

The Hoover Medal was established through a trust fund created by a gift from Conrad N. Lauer, and is to be awarded periodically "to a fellow engineer for distinguished public service" by a board representing the national societies of civil, mining and metallurgical, mechanical, and electrical engineers. The fourth medal was awarded in 1939; no awards have been made since that time.

ALFRED NOBLE PRIZE

This prize, established in 1929, consists of a certificate and a cash award of $500 from the income from a fund contributed by engineers and others to perpetuate the name and achievements of Alfred Noble, past president of the American Society of Civil Engineers and of the Western Society of Engineers. It may be made to a member of any of the co-operating societies, American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, AIEE, or Western Society of Engineers, for a technical paper of particular merit accepted by the publication committee of any of these societies, provided the author, at the time of such acceptance, is not over 30 years of age. No award was made during the past year.

WASHINGTON AWARD

The Washington Award for 1941 was bestowed upon Ralph Budd, "for vision and courageous leadership in advancing the technological frontiers of high-speed railroad transportation", and was presented to him at a dinner on February 24, 1941. This award may be made annually to an engineer by the commission of award composed of nine representatives of the Western Society of Engineers and two each of ASCE AIME, ASME, and AIEE.

Joint Activities

UNITED ENGINEERING TRUSTEES, INC.

This organization is the corporate body which holds title in the name of the four Founder Societies to their joint physical properties, namely, the Engineering Societies Building, the Engineering Societies Library, and the endowment funds of the Engineering Foundation. It operates and manages the Engineering Societies Building and administers certain joint activities of the four Founder Societies.

Extensive studies have been made in efforts to improve the service of the Engineering Societies Building to the members of the societies. Constant efforts have been made to maintain and improve the security of the investments of the corporation, and, to such extent as consistent therewith, to obtain a reasonable income. An abstract of the annual report of the corporation for the year which ended September 30, 1940, appeared on pages 49–50 of ELECTRICAL ENGINEERING for January 1941

ENGINEERING FOUNDATION

The Engineering Foundation is a joint organization of the national societies of civil, mining and metallurgical, mechanical, and electrical engineers established for "the furtherance of research in science and engineering, and the advancement in any other manner of the profession of engineering and the good of mankind".

The Foundation assists in a wide range of research projects of interest to science, engineering, industry, and the general public, each project being under the sponsorship of one of the Founder Societies. Results of the researches are published by the engineering societies, and other organizations. It has continued its financial support of the work of the Engineers' Council for Professional Development.

Under the sponsorship of the Institute the research on stability of impregnated-paper insulation, at the Johns Hopkins University, and the research on insulating oils and cable saturants, at the Massachusetts Institute of Technology, were carried forward with good results. Good progress was made also on the welding research under the joint sponsorship of the American Welding Society and the Institute. A report on this work appeared on page 91 of ELECTRICAL ENGINEERING for February 1941.

A comprehensive abstract of the annual report of the Engineering Foundation for the year which ended September 30, 1940 appeared on pages 50–51 of ELECTRICAL ENGINEERING for January 1941.

In the death of Doctor Otis E. Hovey, its director, on April 14, 1941, the Engineering Foundation suffered a great loss.

ENGINEERING SOCIETIES LIBRARY

The Engineering Societies Library, which was formed by combining the separate libraries of the four national societies of civil, mining and metallurgical, mechanical, and electrical engineers, and the preparation of a composite card catalog, has been expanded as a single engineering library, which probably constitutes the best collection of its type in the United States.

On September 30, 1940, the library had 149,734 volumes, 7,636 maps, and 4,473 bibliographies. Books and pamphlets totaling 5,587 were received during the year ending at that time. Current issues of 1,292 periodicals were received. Over 11,000 entries were added to the index of periodicals, which now contains over 250,000 cards.

Special services rendered by the library include: photoprints, searches, abstracts, translations, bibliographies, book loans by mail, etc. An abstract of the annual report of the library appeared on page 51 of ELECTRICAL ENGINEERING, January 1941.

EMPLOYMENT SERVICE

The boards of the four Founder Societies authorized the incorporation of the jointly operated employment service in the state of New York, as a nonprofit making organization, with the name "Engineering Societies Personnel Service, Inc." The main office is in the Engineering Societies Building, New York.

In the summer of 1940, an office of this new corporation was established in Detroit in co-operation with the Engineering Society of Detroit. As in the past, offices are operated in Chicago and San Francisco, with the co-operation of the Western Society of Engineers in the former, and the Engineers Club of San Francisco in the latter.

The service is supported by the joint contributions of the societies and their individual members who secure positions. An analysis of registration and placement records of this service as reported to the national societies is given in table XI.

ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT

This Council, organized in 1932 to engage in activities leading toward the enhancement of the professional status of the engineer, includes three representatives of each of the eight participating organizations. These are the national societies of civil, electrical, mechanical, and mining and metallurgical engineers, the Society for the Promotion of Engineering Education, the National Council of State Boards of Engineering Examiners, and the Engineering Institute of Canada.

Its principal activities have been carried on by four committees: student selection and guidance, engineering schools, professional training, and professional recognition.

At the annual meeting in October 1940, the Engineering Institute of Canada became, by unanimous vote, the eighth participating body.

Including the actions on engineering curricula taken on October 24, 1940, the record is:

Total curricula submitted, including reinspections	791
Accredited	457
Accredited provisionally	83
Not accredited	164
Reinspections with no change in status	82
Action pending	5

A complete list of accredited curricula appeared on page 523 of ELECTRICAL ENGINEERING for December 1940.

AMERICAN ENGINEERING COUNCIL

Decisions were reached by the board of directors of the Institute and by the board of one of the other Founder Societies not to continue the financial contributions of those societies to the Council beyond the end of 1940. On account of the consequent lack of assurance of the necessary financial support, the activities of the American Engineering Council as a Council were terminated as of December 31, 1940.

A special committee of the AIEE is considering plans for replacing the American Engineering Council.

IWADARE FOUNDATION COMMITTEE

No Iwadare lecturer was chosen to go to Japan for the current year, nor has any Iwadare Fellow come to the United States.

REPRESENTATIVES

In addition to the many divisions of its work represented by its own general and technical committees, the Institute participates in a wide range of activities of interest and importance to engineers and others through its representation upon about 30 joint committees and national bodies.

A list of representatives was published in the September 1940 issue of ELECTRICAL ENGINEERING and in the 1941 Year Book.

Appreciation

The 1940–41 board of directors appreciates the work of the national committees and the District, Section, and Branch officers. The board extends its sincere thanks for the effective conduct for the year of the activities in the respective divisions mentioned. Each division is important. The high degree of enthusiasm and constructive accomplishment evident everywhere shows very efficient leadership. Also the generous interest, allotment of time, and support which the members have accorded the efforts of the officers and each other is deeply appreciated. Without such unselfish and magnificent co-operation there would be no professional standing for electrical engineers such as is provided by the Institute.

Respectfully submitted for the board of directors.

H. H. HENLINE
National Secretary

May 23, 1941

Table XI. Analysis of Employment Service

Month	Men Registered				Men Placed			
	New York	Chicago	San Francisco	Total	New York	Chicago	San Francisco	Total
1940								
May	193	98	119	410	43	17	22	82
June	218	143	93	454	40	16	21	77
July	221	109	89	419	54	16	19	89
August	185	65	69	319	60	29	33	122
September	193	67	50	310	57	35	21	113
October	159	68	70	297	74	31	32	137
November	136	30	51	217	57	30	25	112
December	154	29	59	242	51	33	28	112
1941								
January	162	54	81	297	63	20	38	121
February	162	58	61	281	64	25	24	113
March	197	66	67	330	44	30	43	117
April	166	65	67	298	41	31	35	107
Total	2,146	852	876	3,874	648	313	341	1,302

HASKINS & SELLS
CERTIFIED PUBLIC ACCOUNTANTS

22 EAST 40TH STREET
NEW YORK

May 16, 1941

American Institute of Electrical Engineers,
33 West 39th Street, New York.

Dear Sirs:

We have made an examination of your balance sheet as of April 30, 1941, and of your recorded cash receipts and disbursements for the year ended that date. Our examination consisted of a review of the system of internal control and the accounting procedures of the Institute and examination or tests of its accounting records and other supporting evidence by methods and to the extent we deemed appropriate. We present the following:

Balance Sheet, April 30, 1941 (Exhibit A).
Property and Restricted Funds Securities, Less Reserve for Securities of Doubtful Value (Schedule 1).
Statement of Recorded Cash Receipts and Disbursements of General Fund for the Year Ended April 30, 1941 (Exhibit B).
Statement of Recorded Cash Receipts and Disbursements of Property and Restricted Funds for the Year Ended April 30, 1941 (Exhibit C).

In accordance with the terms of our engagement, members and other debtors, except certain advertisers, were not requested to confirm to us the amounts receivable from them at April 30, 1941. In accordance with the usual practice of the Institute, no provision has been made for dues which may prove to be uncollectible.

In our opinion, subject to the comments in the next preceding paragraph, the accompanying Exhibit A fairly presents your financial condition at April 30, 1941, and the accompanying Exhibits B and C fairly present your recorded cash receipts and your disbursements of funds, as indicated, for the year ended that date.

Yours truly,

HASKINS & SELLS

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Balance Sheet, April 30, 1941

Exhibit A

ASSETS			LIABILITIES		
Property Fund Assets:			**Property Fund Reserve**		$549,947.29
One-fourth interest in the total net assets of United Engineering Trustees, Inc., exclusive of Trust Funds	$498,448.48		**Restricted Fund Reserves:**		
Equipment:			Reserve Capital Fund	$220,255.09	
Library—volumes and fixtures	37,296.37		Pension Fund	10,000.00	
Office furniture and fixtures (less reserve for depreciation, $24,028.08)	7,518.38		Life Membership Fund	9,800.42	
Works of art, etc.	3,001.35		International Electrical Congress of St. Louis Library Fund	5,289.37	
Investment—at cost—Schedule 1	943.73		Lamme Medal Fund	4,374.00	
Cash (see Exhibit C)	2,738.98		Mailloux Fund	1,059.87	
Total property fund assets		$549,947.29	Total restricted fund reserves		249,779.35
Restricted Fund Assets:			Current Liabilities—Accounts payable		13,512.34
Securities—at cost, less reserve for securities of doubtful value (market quotation value, $193,764.44)—Schedule 1	$202,795.99		**Deferred Income:**		
Cash (see Exhibit C)	46,942.53		Dues received in advance	$ 5,331.73	
Accrued interest receivable	40.83		Entrance fees and dues advanced by applicants for membership	591.75	
Total restricted fund assets		249,779.35	Deferred credits for other unallocated receipts	539.75	
Current Assets:			Subscriptions for TRANSACTIONS received in advance	8.00	
Cash (see Exhibit B)	$ 41,617.90		Reserve for prepaid subscriptions for ELECTRICAL ENGINEERING	7,615.73	
Accounts receivable:			Total deferred income		14,086.96
Members—for dues	18,779.17		Surplus		51,576.37
Advertisers	842.62				
Miscellaneous	4,096.36				
Accrued interest receivable	1,439.17				
Inventories:					
TRANSACTIONS, etc.	2,139.75				
Text and cover paper	4,909.31				
Work in process (May issue of ELECTRICAL ENGINEERING)	4,160.13				
Badges	1,191.16				
Total current assets		79,175.57			
Total		$878,902.21	Total		$878,902.21

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Statement of Recorded Cash Receipts and Disbursements of General Fund for the Year Ended April 30, 1941

Exhibit B

Cash on Deposit With The National City Bank of New York, May 1, 1940		$ 32,156.58
Receipts:		
Dues (including $94,662.00 allocated to ELECTRICAL ENGINEERING subscriptions)	$206,324.68	
Advertising	43,084.48	
TRANSACTIONS subscriptions	7,058.67	
ELECTRICAL ENGINEERING subscriptions	15,922.33	
Miscellaneous publications (preprints, standards, TRANSACTIONS supplement, etc.)	16,662.26	
Students' fees	12,794.70	
Entrance fees	7,030.65	
Membership badges	2,037.00	
Transfer fees	1,177.40	
Interest on investments, less purchased interest	6,405.21	
Miscellaneous	186.75	
Total receipts		318,684.13
Total		$350,840.71
Disbursements:		
Publications expense:		
ELECTRICAL ENGINEERING	$ 81,809.51	
TRANSACTIONS	17,710.97	
YEAR BOOK	6,887.57	
Miscellaneous publications (preprints, standards, TRANSACTIONS supplement, etc.)	13,932.02	
Institute meetings	12,867.96	
Institute Sections	40,934.71	
Institute Branches	3,516.42	
Edison Medal committee	159.86	
Finance Committee	741.68	
Headquarters committee	45.22	
Membership committee	8,820.89	
Standards committee	8,731.53	
Technical committees	260.71	
Committee on radio broadcasts	504.06	
Traveling expenses:		
Geographical districts:		
Executive committees	2,702.90	
Vice-presidents	1,008.85	
Branch counselors and chairmen	8,710.97	
President's appropriation	1,098.87	
Board of directors	6,276.05	
National nominating committee	1,136.22	
Forward	$217,856.97	$350,840.71
Total—(Forward)		$350,840.71
Disbursements—(Forward)	$217,856.97	
Administrative expenses	48,259.38	
Geographical districts—paper prizes	306.78	
Institute prizes	237.27	
American Co-ordination Committee on Corrosion	25.00	
American Engineering Council	4,150.00	
American Standards Association	1,500.00	
United Engineering Trustees, Inc.:		
Building assessment	10,984.81	
Library assessment	10,000.98	
Engineering Societies Employment Service	1,168.70	
Engineers' Council for Professional Development	850.00	
Engineering Foundation projects:		
Insulating oils and cable saturants	250.00	
Welding research	250.00	
Research on impregnated paper insulation	250.00	
National Fire Protection Association—dues	60.00	
United States Committee of International Commission on Illumination	300.00	
Membership badges	2,256.37	
Legal services	250.00	
John Fritz Medal	50.00	
Lamme Medal	181.30	
Transfer to Pension Fund	10,000.00	
Miscellaneous	35.25	
Total disbursements		309,222.81
Cash on Deposit With The National City Bank of New York, April 30, 1941		$ 41,617.90

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Statement of Recorded Cash Receipts and Disbursements of Property and Restricted Funds for the Year Ended April 30, 1941

Exhibit C

	Restricted Funds							
	Reserve Capital Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund	Pension Fund	Total Restricted Funds	Property Fund (Equipment Replacements)
Cash on Deposit With The National City Bank of New York and Various Savings Banks, May 1, 1940	$ 44,911.26	$3,445.09	$ 857.62	$14.00	$1,028.83		$ 50,256.80	$3,330.32
Receipts:								
Interest on bonds and dividends on stock	$ 250.00	$ 141.75	$48.00				$ 439.75	
Interest on bank balance	47.77			$ 11.04			58.81	
Proceeds from sale and redemption of securities	$146,476.93	4,290.00					150,766.93	$5,555.72
Transfer from general fund						$10,000.00	10,000.00	
Donations, purchase of life membership, etc.		283.92			20.00		303.92	
Total receipts	$146,476.93	$ 581.69	$4,431.75	$48.00	$ 31.04	$10,000.00	$161,569.41	$5,555.72
Total	$191,388.19	$4,026.78	$5,289.37	$62.00	$1,059.87	$10,000.00	$211,826.21	$8,886.04
Disbursements:								
Annual withdrawal authorized by by-laws		$ 553.44					$ 553.44	
Gold and bronze replicas of Lamme medal and certificate (portion of cost)				$38.00			38.00	
Purchase of securities	$164,292.24						164,292.24	
Equipment replacements, alterations, and repairs								$6,147.06
Total disbursements	$164,292.24	$ 553.44		$38.00			$164,883.68	$6,147.06
Balance on Deposit With The National City Bank of New York and Various Savings Banks, April 30, 1941	$ 27,095.95	$3,473.34	$5,289.37	$24.00	$1,059.87	$10,000.00	$ 46,942.53	$2,738.98

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Property and Restricted Funds Securities, Less Reserve for Securities of Doubtful Value, April 30, 1941

Schedule 1

	Principal Amount of Bonds or Number of Shares of Stock	Restricted Funds				Property Fund (Equipment Replacements)
		Reserve Capital Fund	Life Membership Fund	Lamme Medal Fund	Total Restricted Funds	
Railroad Bonds:						
Allegheny Corporation 20-year collateral trust convertible 5%, due 1949	$15,000.00	$ 10,627.50			$ 10,627.50	
Baltimore & Ohio Railroad Company 6% refunding and general mortgage series C, due 1995 (stamped)	12,000.00	8,940.00		$4,330.00	13,270.00	
Central of Georgia Railway Company 5% consolidated mortgage, due 1945	3,000.00	1,477.50			1,477.50	
Chicago & Erie Railroad Company 5% first mortgage, due 1982	1,000.00	1,105.00			1,105.00	
Chicago & Northwestern Railway Company 6½% due March 1, 1936	9,000.00	7,202.50			7,202.50	
Florida East Coast Railway Company 5% first and refunding mortgage series A, due 1974 (certificates of deposit)	10,000.00	9,818.75			9,818.75	
New York Central Railroad Company 5% refunding and improvement mortgage series C, due 2013	6,000.00	5,742.50			5,742.50	
Northern Pacific Railway Company 6% refunding and improvement mortgage series B, due 2047	10,000.00	10,962.50			10,962.50	
St. Louis-San Francisco Railway Company 5% prior lien mortgage series B, due 1950 (certificates of deposit)	6,000.00	5,497.50			5,497.50	
Texas and Pacific Railway Company general and refunding series B 5%, due 1977	5,000.00		$5,306.25		5,306.25	
Western Pacific Railroad Company 5% series A, due 1946 (stamped)	15,000.00	7,225.00			7,225.00	
Total railroad bonds		$ 68,598.75	$5,306.25	$4,330.00	$ 78,235.00	
Public Utility Bonds:						
New York & Queens Electric Light & Power Company 3½% first and consolidated mortgage, due 1965	$10,000.00	$ 11,000.00			$ 11,000.00	
Bond and Real Estate Mortgage:						
Fidelity Union Title and Mortgage Guaranty Company first mortgage certificates (on property 75–79 Prospect Street, East Orange, N. J.) 4%, due 1944	14,152.05	$ 13,208.32			$ 13,208.32	$943.73
United States Government Bonds:						
Treasury bonds 2%, due 1950/48	77,000.00	$ 78,130.94			$ 78,130.94	
Treasury Savings bonds series D, due July 1, 1949	10,000.00	7,644.00			7,644.00	
Treasury Savings bonds series D, due January 1, 1950	10,000.00	7,500.00			7,500.00	
Total United States Government bonds		$ 93,274.94			$ 93,274.94	
Capital Stocks:						
American Telephone & Telegraph Company	30 shares	$ 4,897.95			$ 4,897.95	
Commercial Investment Trust Corporation 4¼% preferred, series of 1935	100 "	10,100.00			10,100.00	
Commonwealth Edison Company	200 "	7,580.68			7,580.68	
E. I. du Pont de Nemours Company	40 "	6,398.20			6,398.20	
General Electric Company	130 "	4,463.80			4,463.80	
International Match Realisation Co., Ltd. voting trust certificates for capital shares of International Match Corporation	6 "	2,094.15			2,094.15	
Union Carbide & Carbon Corporation	70 "	4,858.35			4,858.35	
Total capital stocks		$ 40,393.13			$ 40,393.13	
Total		$226,475.14	$5,306.25	$4,330.00	$236,111.39	$943.73
Less Reserve for Securities of Doubtful Value:						
Central of Georgia Railway Company 5% consolidated mortgage, due 1945	$ 3,000.00	$ 1,477.50			$ 1,477.50	
Chicago & Northwestern Railway Company 6½%, due March 1, 1936	9,000.00	7,202.50			7,202.50	
Florida East Coast Railway Company 5% first and refunding mortgage series A, due 1974	10,000.00	9,818.75			9,818.75	
International Match Realization Co., Ltd. voting trust certificates for capital shares of International Match Corporation	6 shares	2,094.15			2,094.15	
St. Louis-San Francisco Railway Company 5% prior lien mortgage series B, due 1950	$ 6,000.00	5,497.50			5,497.50	
Western Pacific Railroad Company 5% series A, due 1946 (stamped)	15,000.00	7,225.00			7,225.00	
Total reserve for securities of doubtful value		$ 33,315.40			$ 33,315.40	
Total Property Fund Securities						$943.73
Total Restricted Funds Securities, Less Reserve		$193,159.74	$5,306.25	$4,330.00	$202,795.99	

District • • • •

Five Districts Announce Prize Awards for Papers

District prizes for AIEE papers have been announced by five Districts to date. The awards are for papers presented during 1940, except Branch papers, which must have been presented during the academic year ending June 30, 1940.

District 1

Prize for best paper was awarded to W. Mikelson (A'40) and H. W. Bousman (A'25, M'36) for their paper "Rapid-Recording A-C Bridge," presented at the summer convention, Swampscott, Mass., June 24–28, 1940.

Prize for initial paper was awarded to H. R. Mealil (A'37), P. C. Michel, M. W. Scheidorf (A'38), and T. M. Dickinson for their paper "Measurements at Radio Frequencies," presented at the summer convention, Swampscott, Mass., June 24–28, 1940.

Prize for Branch paper was awarded to Thomas F. C. Muchmore (Enrolled Student) for his paper "A Study of Fluorescent Lamps," presented at a student convention held at Rensselaer Polytechnic Institute, Troy, N. Y., May 4, 1940. Honorable mention was made of the paper "Measurement of the Quadrature Synchronous Reactance Using Negative Field Excitation," by H. T. Marcy (Enrolled Student) presented at the same convention.

District 2

Prizes for best paper and initial paper were awarded to K. J. Knudsen (M'38) for his paper "An Improved Frequency Meter for Commercial Power Frequencies," presented at a meeting of the Cleveland Section, December 3, 1940.

District 6

Prize for Branch paper was awarded to Stanley R. Case (A'41) for his paper "Frequency Control," presented at the 13th annual district conference on student activities, Grand Forks, N. Dak., April 19–20, 1940.

District 9

Prize for best paper was awarded to W. A. Leidigh (A'30) for his paper "Space Radio Emergency Trouble Dispatching Applications for the Public Utility," presented at a meeting of the Portland Section, April 25, 1940.

Prize for initial paper was awarded to G. D. Sheckels (A'39) for his paper "Wind Shielding of Parallel Conductors on Distribution Lines," presented at a meeting of the Seattle Section, December 17, 1940.

Prize for Branch paper was awarded to G. L. Hollingsworth (Enrolled Student) for his paper "An Electronic Voltage Regulator," presented at a joint meeting of the Portland Section and the Oregon State College Branch, Corvallis, Oregon, May 18, 1940.

District 10

Prize for best paper was awarded to W. J. Moulton-Redwood (A'20, M'35) for his paper "Safeguarding the Human Units of Industry," presented at a meeting of the Toronto Section, December 13, 1940.

Prize for initial paper was awarded to Harold R. Osborne (A'37) for his paper "Voltage Regulators for Small and Medium Power Loads," presented at a meeting of the Toronto Section, January 12, 1940.

Section • • • •

Michigan Entertains Past Chairmen at Dinner Meeting

The past chairmen of the Michigan Section were guests of honor at a dinner meeting May 20, 1941, at the Dearborn Country Club, Dearborn, Mich. Since its founding as the Detroit-Ann Arbor Section in 1911, 29 men have served as chairmen, 18 of whom were present at the dinner. The 1940–41 chairman, E. V. Sayles, presided. Doctor Benjamin F. Bailey (A'07, F'21), head of the electrical-engineering department, University of Michigan, as speaker of the evening, reviewed the early history of the electrical art, with especial reference to developments which were made in Michigan.

The accompanying illustration shows the group assembled at the dinner, with the past chairmen, present Section officers, and Doctor Bailey at the speaker's table.

The past chairmen who attended the dinner are:

A. A. Meyer, 1916–17, engineer, electrical system, Detroit Edison Company, Detroit; G. E. Lewis, 1918–19, superintendent, Huron River water power, Detroit Edison Company, Ann Arbor; J. H. Cannon, 1922–23, professor of electrical engineering, University of Michigan, Ann Arbor; E. L. Bailey, 1923–24, electrical engineer, Chrysler Corporation, Detroit; G. B. McCabe, 1925–26, engineer on cable practice, Detroit Edison Company; Harold Cole, 1926–27, distribution engineer, Detroit Edison Company; F. H. Riddle, 1927–28, director of research, ceramic division, Champion Spark Plug Company, Detroit; A. H. Lovell, 1928–29, assistant dean and secretary, college of engineering, University of Michigan; L. F. Hickernell, 1929–30, chief engineer, Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y.; LeRoy Braisted, 1930–31, Braisted and Blair, manufacturers' agents; O. E. Hauser, 1932–33, engineer, meter department, Detroit Edison Company; R. Foulkrod, 1933–34, plant extension engineer, Michigan Bell Telephone Company, Detroit; J. R. North, 1934–35, assistant electrical engineer, Commonwealth and Southern Corporation, Jackson; H. P. Seelye, 1935–36, senior engineer, engineering division, Detroit Edison Company; S. S. Attwood, 1936–37, professor of electrical engineering, University of Michigan; D. H. Baker, 1937–38, transmission and protection engineer, Michigan Bell Telephone Company; R. E. Greene, 1938–39, assistant construction engineer, Detroit Edison Company; W. G. Knickerbocker, 1939–40, assistant superintendent of meters, Detroit Edison Company.

The Michigan Section honors its past chairmen, with present Section officers and guest speaker, also at the speaker's table

The following have also served as chairmen of the Section:

C. L. de Muralt, 1911–12; J. J. Woolfenden, 1912–13; A. R. Sawyer, 1913–14; H. H. Norton, 1914–15; R. Collamore, 1915–16; H. H. Higbie, 1917–18; J. C. Parker, 1919–20; C. Kittredge, 1920–21; A. S. Albright, 1921–22; F. L. Snyder, 1924–25; J. J. Shoemaker, 1931–32.

Branch • • • •

District 7 Student Convention

The Student Branches of the AIEE South West District (7) held a convention and conference at the University of Missouri, Columbia, April 28–29, 1941. The program included five technical sessions, an inspection of the University engineering laboratories, a banquet and dance, in addition to business meetings of counselors and of Branch chairmen following the luncheon for chairmen, counselors, and faculty on April 29.

At the meeting of Branch counselors, it was voted to hold the next District conference on student activities at St. Louis, Mo., October 8–10, 1941, in connection with the South West District meeting. It was voted to omit student papers at that conference. R. S. Glasgow, Washington University, was elected chairman of the District committee on student activities for 1941–42. The meeting recorded its belief that the AIEE national committee on Student Branches should be made up of the chairmen of the various District committees on student affairs, and that one of its members should be elected chairman by the committee.

The meeting of Branch chairmen discussed the publication of a mimeographed bulletin for distribution to the various Branches, listing suggestions for activities, good technical films, good speakers, and news of interest. It was voted to establish such a bulletin, to be published four times during the academic year by the Branch whose counselor was chairman of the District committee on student activities, and to be financed if possible by the national treasury.

The program of the technical sessions follows:

Monday, April 28

10:00 a.m.

Chairman, John Gibson, Oklahoma Agricultural and Mechanical College

Timekeeper, Lacy Goostree, Southern Methodist University

THE FLOURESCENT LAMP. **C. I. Fleissner,** New Mexico State College

PHOTOELECTRIC CELLS IN INDUSTRY. **R. C. Prim, 3rd,** Texas University

ELECTRIC CONTROLS IN AIR CONDITIONING. **Bill Cage,** Southern Methodist University

AN INDICATING SLIP METER. **Edward Dinger,** University of Missouri

1:45 p.m.

Chairman, Hugh Grandberry, Texas Technological Institute

Timekeeper, Emmett Welch, University of Oklahoma

ELIMINATION OF VIBRATION IN STEAM-TURBINE ROTORS. **E. L. Cheeseman,** Texas University

MATHEMATICAL ANALYSIS OF NONLINEAR CIRCUITS. **O. M. Martin,** Texas Agricultural and Mechanical College

COMMUTATION CURRENTS. **John Laidig and G. A. Richardson,** University of Kansas

3:00 p.m.

Chairman, H. Zeidler, Kansas State College

Timekeeper, Walter Evans, Washington University

LOCALIZED ANNEALING OF ROCK-BIT BODIES BY 60-CYCLE INDUCTION HEATING. **L. K. Davis and B. W. Pike,** Rice Institute

A HIGH-FREQUENCY AMMETER. **P. E. Chapman, Jr.,** Washington University

GAMMA-RAY WELL LOGGING. **Chester Copmann, Jr.,** Oklahoma Agricultural and Mechanical College

Tuesday, April 29

9:00 a.m.

Chairman, Kenneth Urquhart, University of New Mexico

Timekeeper, L. K. Davis, Rice Institute

HIGH-IMPEDANCE VACUUM-TUBE WATTMETER. **R. S. Hoff,** Texas Agricultural and Mechanical College

CONSIDERATIONS IN THE DESIGN OF RADIO-FREQUENCY COILS. **W. J. Bennetsen and A. M. Reagan,** Missouri School of Mines and Metallurgy

A HIGH-GAIN PENTODE AMPLIFIER STAGE. **S. H. Buder,** Washington University

10:15 a.m.

Chairman, B. H. Eldridge, University of Texas

Timekeeper, T. E. Duce, Texas Agricultural and Mechanical College

INVERSE FEEDBACK APPLIED TO RADIO BROADCASTING EQUIPMENT. **R. I. Meisenheimer,** Kansas State College

A PRIVACY SYSTEM USING FREQUENCY TRANSLATION. **J. B. Parchman,** Rice Institute

A DEMONSTRATION UNIT FOR STUDYING TELEVISION PRINCIPLES. **Harold Fristoe,** University of Arkansas

District 5 Student Conference

A conference of the Student Branches in the Great Lakes District was held at Illinois Institute of Technology, Chicago, May 17, 1941, with 15 of the 16 Branches represented and a total attendance of about 100. The program included a student technical session, a luncheon, and business meeting. Speakers were District Vice-President K. L. Hausen and A. J. Krupy, chairman of the Chicago Section committee on young engineers and student members.

At the business meeting, the following were elected as the executive committee of the District committee on student activities for the coming year: R. R. Benedict, University of Wisconsin, *chairman;* M. M. Cory, Michigan State College, *senior member;* H. O. Warner, University of Detroit, *junior member.* Reports of Branch activities for the past year were presented.

The following student papers were presented at the technical session:

FLUORESCENT LIGHTING. **Carlton Souder,** Iowa State University

CONSTRUCTION AND OPERATING CHARACTERISTICS OF AN ELECTROSTATIC AIR CLEANER. **John Kanter,** University of Michigan (graduate student)

HYSTERA-EDDY CURRENT LOSSES. **Gerhard Liedholz,** University of Michigan

CONTROL OF OSCILLATION IN PUBLIC ADDRESS SYSTEM BY PERIODIC PHASE REVERSAL. **M. G. Haugen,** University of Minnesota

THE ENGINEERS' REGISTRATION LAW. **W. H. Hales,** Rose Polytechnic Institute

A SIMPLE HIGH-FREQUENCY DIRECTIONAL ANTENNA ARRAY. **C. A. Mensley,** University of Illinois

THE TESTING OF PRIMARY METERS FOR PRIMARY CUSTOMERS. **A. J. Breslin,** University of Detroit

A SIMPLIFIED SCHEDULE FOR THE ANALYSIS OF A NONSINUSOIDAL WAVE BY THE GRAPHICAL METHOD. **M. Poliak,** Illinois Institute of Technology

Number 1998615. **James Wagner,** Marquette University

Personal • • •

M. A. Edwards (M'40) consulting engineering laboratory, General Electric Company, Schenectady, N. Y., co-author with D. R. Shoults (A'35) and F. E. Crever (A'27) of the paper "Industrial Applications of Amplidyne Generators", has received the 1940 AIEE national prize for best paper in engineering practice. The prize was awarded jointly for this paper and one by J. W. Milnor (A'13, F'30). Mr. Edwards was born March 22, 1905, in Chautauqua, Kans., and received the degrees of bachelor of science in electrical engineering, 1928, bachelor of science in mechanical engineering, 1929, and mechanical engineer, 1934, from Kansas State College of Agriculture and Applied Science. In 1928 he became assistant plant engineer for the National Refining Company, Coffeyville, Kansas, and in 1929 entered the test department of the General Electric Company. He was later transferred to the radio consulting department, and from 1934 to 1937 was in a consulting capacity in regard to the application of thyratron tubes, and was in charge of the development of a new milk-pasteurizing control. Since 1937 he has been in charge of the development of a new high-speed generator known as the amplidyne. He received a Coffin Award in 1934, for his work in developing a new fire-control system for the United States Navy, and a second in 1940 for his work on the amplidyne generator. He is the author of several technical papers.

J. W. Milnor (A'13, F'30) transmission engineer, Western Union Telegraph Company, New York, N. Y., has received the 1940 AIEE national prize award for the best paper in engineering practice for his paper "Control of Inductive Interference to Telegraph Systems". The prize was awarded

M. A. EDWARDS

J. W. MILNOR

D. R. SHOULTS

F. E. CREVER E. C. STARR F. J. GIVEN V. E. LEGG W. H. HUGGINS

jointly for this paper and one by D. R. Shoults (A'35), M. A. Edwards (M'40), and F. E. Crever (A'27). Born October 25, 1889, in Williamsport, Pa., Mr. Milnor received the degree of electrical engineer from Lehigh University in 1912. In 1912 he entered the laboratory of the General Electric Company, Pittsfield, Mass., and in 1913 joined the engineering department of the Western Union Telegraph Company. In 1919 he was made research engineer, and has been transmission engineer since 1936. In 1939 he was in charge of the development of a system now in service for sending of photographs by submarine cable from London to New York. He has been co-chairman of the plant co-ordination committee of the Edison Electric Institute and the Western Union Telegraph Company since 1934. He is a member of the Institute protective devices committee and is also a member of the Institute of Radio Engineers and Tau Beta Pi. He is the owner of several patents, and author of many technical articles.

D. R. Shoults (A'35) industrial engineering department, General Electric Company, Schenectady, N. Y., co-author with M. A. Edwards (M'40) and F. E. Crever (A'27) of the paper "Industrial Applications of Amplidyne Generators", has received the 1940 AIEE national prize award for best paper in engineering practice. The prize was awarded jointly for this paper and one by J. W. Milnor (A'13, F'30). Mr. Shoults was born June 23, 1903, in Storms, Ohio. He received the degree of bachelor of science in electrical engineering from the University of Idaho, 1925. In 1925 he joined the General Electric test department and continued in that department until 1928 when he was transferred to the industrial engineering department. He was engaged in commercial engineering involving application of all types of electrical equipment to the paper, lumber, and rubber industries. In 1937 he won the Coffin Award for a study of the pull-in torques of synchronous motors. Shortly after this he started the study of amplidyne control, and in March 1941, was sent to London on a government mission. He is the author of several technical publications.

F. E. Crever (A'27) engineer, General Electric Company, Schenectady, N. Y., co-author with D. R. Shoults (A'35) and M. A. Edwards (M'40) of the paper "Industrial Applications of Amplidyne Generators", has received the 1940 AIEE national prize for best paper in engineering practice. The prize was awarded jointly for this paper and one by J. W. Milnor (A'13, F'30). Mr. Crever was born in Nebraska, August 23, 1903. He received the degrees of bachelor of arts, 1925, and electrical engineer, 1926, from Stanford University. In 1926 he entered the test course of the General Electric Company at Schenectady, and in 1928 was made assistant foreman of the test course. He became construction foreman for the company's central district in 1929. In 1937 he was transferred to the generator voltage regulator department, and in 1938 was appointed administrative assistant in this department, the position which he now holds.

E. C. Starr (M'29) professor of electrical engineering, Oregon State College, Corvallis, and consulting engineer for the Bonneville Power Administration, Portland, Ore., has received the 1940 AIEE prize for the best paper in theory and research for the papers "High-Voltage D-C Point Discharges" and "Aircraft Precipitation-Static Radio Interference". He was born August 6, 1901, in Falls City, Ore. and received the degrees of bachelor of science in electrical engineering, 1923, and electrical engineer, 1938, from Oregon State College. From 1923 to 1927 he was employed in the testing department and the high-voltage laboratory of the General Electric Company, Schenectady, N. Y., and Pittsfield, Mass. In 1927 he became instructor of electrical engineering, Oregon State College, and subsequently became assistant professor, 1931, associate professor, 1937, and professor, 1939. Since 1939 he has also been consulting engineer for the Bonneville Power Administration, Portland, Oregon. He is now administering a defense research project for the National Defense Research Committee. He is also a member of Eta Kappa Nu, Tau Beta Pi, and Sigma Xi, and is the author of numerous technical publications.

F. J. Given (A'28) apparatus development department, Bell Telephone Laboratories, Inc., New York, N. Y., co-author with V. E. Legg (A'37) of the paper "Compressed Powdered Molybdenum Permalloy for High-Quality Inductance Coils", has received the 1940 AIEE national prize award for initial paper. He was born November 7, 1896, in Woburn, Mass., and received the degree of bachelor of science from Harvard University and the Massachusetts Institute of Technology in 1919. From 1919 to 1925 he was design engineer and supervising engineer with the Western Electric Company, New York, N. Y., and with the formation of Bell Laboratories, Inc., in 1925, was employed in a supervisory capacity in the apparatus development department of that company, a position which he still holds.

V. E. Legg (M'37) apparatus development department, Bell Telephone Laboratories, Inc., New York, N. Y., co-author with F. J. Given (A'28) of the paper "Compressed Powdered Molybdenum Permalloy for High-Quality Inductance Coils", has received the 1940 AIEE national prize award for initial paper. Mr. Legg was born in Ann Arbor, Mich., April 26, 1897, and received the degrees of bachelor of arts, 1920, and master of science, 1922, from the University of Michigan. During 1920–1921 he was research physicist with the Detroit Edison Co., Detroit, Mich. Since 1923 he has been employed at the Bell Telephone Laboratories, Inc., engaged in the development of magnetic materials and their application. He holds numerous patents and is the author of several technical articles.

W. H. Huggins (Enrolled Student) Oregon State College, Corvallis, Ore., has received the 1940 AIEE national prize award for Branch paper for his paper "A Stabilized Neon-Tube Direct-Coupled Amplifier". Mr. Huggins was born January 11, 1919, in Rupert, Idaho, and received the degree of bachelor of arts from Oregon State College in 1941. In 1939 he received the award given annually by the Pi chapter of Eta Kappa Nu to the outstanding sophomore in electrical engineering. He was chairman of the Oregon State College Branch AIEE, 1940–41, is a student member of the Institute of Radio Engineers, and is a member of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu. During the next year he will be engaged in the study of aircraft precipitation-static radio interference for the National Defense Research Council.

W. I. Slichter (A'00, F'12) professor and head of the department of electrical engineering at Columbia University, New York, N. Y., retired in June 1941. Born May 7, 1873, in St. Paul, Minn., Mr. Slichter received the degree of electrical engineer from

the Columbia University School of Mines in 1896. He entered the test department of the General Electric Company, Schenectady, N. Y., in 1896, and the following year became assistant to Doctor C. P. Steinmetz, in which capacity he carried on experimental work in construction and design of motors. He later was made assistant to the technical director of the company, and in 1910 was appointed professor of electrical engineering and head of that department at Columbia University. He has been national treasurer of the Institute since 1930, was a director from 1918 to 1922, vice-president, 1922–24, and has been active on many Institute committees. He has also served on the library board of United Engineering Trustees, Inc., the Engineering Foundation Board, the engineering societies monographs committee, and the advisory board of the National Bureau of Engineering Registration. He is also a member of The American Society of Mechanical Engineers, the Society for the Promotion of Engineering Education, and other societies, and is the author of numerous technical papers.

F. W. Bush (A'36) formerly sales engineer, transformer division, of the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been made engineer in charge of transformer sales. **W. C. Sealey** (A'25, M'38) of the transformer division of the company has been appointed engineer in charge of transformer design. Mr. Bush received the degree of bachelor of science in electrical engineering from the Georgia School of Technology in 1928, and joined the Allis-Chalmers Manufacturing Company in that year as graduate student apprentice. In 1930 he was made assistant engineer in the transformer engineering department, and in 1932 was appointed engineer in charge of the high-voltage impulse laboratory of the company. He became sales engineer about 1938. Mr. Sealey received the degree of bachelor of science in electrical engineering from the Carnegie Institute of Technology in 1922, and entered the student course of the Westinghouse Electric and Manufacturing Company. In 1923 he was transferred to the transformer department of the company as design engineer, and in 1928 became electrical engineer in charge of designing power transformers for the American Brown Boveri Electric Corporation, Camden, N. J. When that company was taken over by the Allis-Chalmers Manufacturing Company in 1931, he became electrical engineer in the transformer department of the latter company.

H. F. Boe (M'30) formerly manager of the service department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been made manager of the newly designated district manufacturing and repair department. **C. A. Powel** (M'20) formerly manager of the industry engineering department has been named to the newly created position of manager of the headquarters engineering departments. His place will be filled by **A. C. Monteith** (A'25, M'40) formerly manager of the central station engineering department, who will be succeeded by **C. F. Wagner** (A'20, F'40) consulting transmission engineer. **H. W. Tenney** (M'36) who was manager of the engineering laboratories and standards department has been appointed assistant director of research, and will be succeeded in the laboratories and standards department by **Thomas Spooner** (A'12, F'29) formerly manager of the research laboratories. **M. B. Wyman** (A'30, M'35) has been named manager of the newly designated district engineering and service department. **T. R. Langan** (A'13, M'30) formerly traffic manager at Pittsburgh, Pa., has been made assistant to the general manager of purchases and traffic, in Washington, D. C. **J. S. Parry, Jr.** (A'40) formerly sales supervisor for the company at Newark, N. J., is now manager of the Newark sales office.

L. H. Hill (A'22, F'38) formerly assistant manager, electrical department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been elected vice-president and will head a newly created industrial relations department. Mr. Hill was born March 8, 1899, at Toms River, N. J., and received the degree of electrical engineer from Cornell University in 1922. He became a design engineer in the transformer engineering department of the Westinghouse Electric and Manufacturing Company, in 1922, and was placed in charge of power transformer development in 1925. He became manager of the transformer division of the American Brown Boveri Company, Camden, N. J., in 1928, continuing as assistant engineer in charge of the transformer division with the Allis-Chalmers Company when it took over the American Brown Boveri Company in 1931. He was appointed engineer-in-charge of the transformer division in 1936. His appointment as assistant manager of the company's electrical department was announced in the May issue, page 232.

B. R. Teare, Jr. (A'29, M'36) professor of electrical engineering, Carnegie Institute of Technology, Pittsburgh, Pa., has received honorable mention in the 1940 AIEE national prize award for best paper in theory and research, for his paper "Theory of Hysteresis Motor Torque". Born January 12, 1907, in Menomonie, Wis., he received the degrees of bachelor of science, 1927, and master of science, 1928, from the University of Wisconsin, and that of doctor of engineering from Yale University, 1937. He was with the General Electric Company, Schenectady, N. Y., from 1929 to 1933, in the testing department and the engineering general department. He was a member of the engineering faculty, Yale University, New Haven, Conn., as instructor and assistant professor from 1933 to 1939, when he became professor of electrical engineering at Carnegie Institute of Technology. He holds several patents and is the author of numerous technical publications.

J. E. Bevan (A'39) manager of the switchboard division of the Roller-Smith Company, Bethlehem, Pa., has been appointed vice-president in charge of manufacturing operations. Mr. Bevan was born December 16, 1904, in Frackville, Pa., and received the degree of bachelor of science in electrical engineering from Lehigh University in 1925. After a year with the Bethlehem Steel Company as engineer in the plant electrical maintenance department, he became associated with the Philadelphia Electric Company, Philadelphia, Pa., in 1927, and was engaged in substation and generating station maintenance. In 1928 he joined the Roller-Smith Company, doing work in the field of factory production and cost research, sales engineering, oil and air circuit breaker design and power switchboard design. He later became assistant chief engineer for the company.

J. H. Payne (A'12, M'32) formerly chief of the electrical and radio division of the United States Department of Commerce, Washington, D. C., has become a member of the Rockefeller Foundation group of the National Defense Council at New York, N. Y., designed to co-ordinate commercial and cultural relations between the American republics. Mr. Payne received the degree of bachelor of science in electrical engineering from Armour Institute of Technology in 1905. From 1905 to 1919 he was with the Westinghouse Electric and Manufacturing Company, in Chicago, Ill., and New York, N. Y. In 1920 he joined the Westinghouse Electric International Company, New York, N. Y., and Washington, D. C., and became manager of the department of Europe and later manager of the power department. He transferred to his recent position with the Department of Commerce about 1936.

W. V. Brown (A'21) has recently retired as manager of the Engineering Societies Employment Service, New York, N. Y. Mr. Brown was born in Oldtown, Me., August 17, 1874, and received the degree of bachelor of science in electrical engineering from the Massachusetts Institute of Technology, Cambridge, Mass., 1894. From 1895 to 1897 he was employed as electrical draftsman with Hatzel and Buehler, New York, N. Y.; from 1897 to 1906 as assistant electrical engineer for Pattison Brothers, New York, and from 1906 to 1914 in the New York City Department of Water Supply, Gas, and Electricity. From 1914 to 1918 he was in the technology department of the New York Public Library, and was manager of the American Engineering Service, before becoming manager of the Engineering Societies Employment Service in 1918.

R. W. Ager (A'24) assistant professor of electrical engineering at the University of California, Berkeley, Calif., has been appointed associate professor of electrical engineering at Cornell University, Ithaca, N. Y. He received the degree of bachelor of science in electrical engineering from the California Institute of Technology in 1922. After a year as junior electrical engineer with the Los Angeles Bureau of Power and Light, he became an inspector for the Southern California Edison Company, Los Angeles. In 1929 he received a teaching fellowship at the California Institute of Technology, and in 1934, after a year as adjunct professor at the College of Mines and Metallurgy of Texas, became assistant professor of electrical engineering at the University of California.

F. W. Hehre (A'13, F'29) professor of electrical engineering at Columbia University,

New York, N. Y., has been named head of the department of electrical engineering. Mr. Hehre was born November 1, 1886 in New York, N. Y., and received the degree of electrical engineer from Columbia University in 1908. For a year after receiving his degree he was employed in the inspection department of the New York Edison Company, New York, N. Y., and in 1909 became a tutor of electrical engineering at Columbia University. He was made an instructor of electrical engineering in 1910, became assistant professor in 1916, associate professor in 1924, and was made full professor in 1938. He is co-author of "Electrical Circuits and Machinery", and author of technical articles.

H. E. Edgerton (A'27, M'32) associate professor of electrical engineering, Massachusetts Institute of Technology, Cambridge, Mass., has been awarded the Potts gold medal of the Franklin Institute for his achievements in the field of high-speed motion pictures. Mr. Edgerton was born April 6, 1903, in Fremont, Nebr., and received the degrees of bachelor of science in electrical engineering, University of Nebraska, 1925, and master of science, 1927, and doctor of science, 1931, Massachusetts Institute of Technology. In 1928 he became an instructor in electrical engineering at the Massachusetts Institute of Technology, and was made assistant professor of electrical engineering in 1932 and associate professor in 1939.

C. S. Beattie (A'27, M'40) formerly assistant sales manager of the Delta-Star Electric Company, Chicago, Ill., has been made manager of engineering for the company. He was born August 28, 1898, in Newark, N. J., and following his graduation from Rutgers College in 1923 with the degree of bachelor of science, became general engineer with the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. In 1925 he joined the Public Service Production Company, Newark, N. J., as design engineer. He was design engineer for the United Engineers and Constructors, Inc., of Newark, N. J., from 1927 to 1930, and in 1930 joined the Delta-Star Electric Company as design engineer, later being transferred to the sales engineering department.

Andrew Alford (A'39) engineer with the Mackay Radio and Telegraph Company, New York, N. Y., co-author with W. E. Jackson, P. F. Byrne, and H. B. Fischer of the paper "The Development of the Civil Aeronautics Authority Instrument Landing System at Indianapolis", has received honorable mention in the 1940 AIEE national prize award for best paper in engineering practice. Mr. Alford was born August 5, 1904, in Samara, Russia, and received the degree of bachelor of arts from the University of California. He has been with the Mackay Radio and Telegraph Company since 1933. He is the author of several technical publications.

Marion Penn (M'21, F'35) general manager of the electric department, Public Service Electric and Gas Company, Newark, N. J., has been elected a director of the Public Service Corporation of New Jersey. After receiving the degree of bachelor of science in electrical engineering from Purdue University in 1911, he was employed in the testing department of the General Electric Company, Schenectady, N. Y., until 1914. He then became affiliated with the Public Service Electric and Gas Company later serving as superintendent of various branches until he was made general manager in 1935.

W. M. McCauley (A'36) formerly manager of sales for the Railway and Industrial Engineering Company, of Greensburg, Pa., has been elected commercial vice-president of the company. Mr. McCauley was born in Ligonier, Pa., February 22, 1894. He attended Lehigh University, and in 1915 became a draftsman for the Railway and Industrial Engineering Company. After the World War he was made manager of the Pittsburgh district sales office, and in 1929 returned to Greensburg as manager of sales. He is also vice-president of Eastern Power Devices, Ltd., of Toronto.

E. R. Shute (M'17) vice-president of the Western Union Telegraph Company, has been commissioned as a lieutenant-colonel in the United States Army Signal Corps Reserve, and has been assigned to the advisory council of communications officials, where he will act as a consultant in problems of communications development for national defense. Mr. Shute is chairman of the telegraph committee of the Defense Communications Board. He has been with Western Union since 1912, and was made vice-president in 1939.

E. E. Johnson (A'25, M'40) engineer of the aeronautics division of the General Electric Company, Schenectady, N. Y., has been made assistant engineer of the aeronautics and marine engineering department. **R. H. Chadwick** (A'17, M'26) formerly engineer of the specialty transformer department, at the company's Fort Wayne, Ind., works, has been appointed assistant to the manager in charge of engineering, and **E. J. Thomas** (A'34) has been made engineer of the specialty transformer department.

R. H. Smith (M'36) manager, sales development and application engineering for the Reliance Electric and Engineering Company, Cleveland, Ohio, has been made manager of applied engineering for that company. He has been with the company since 1923, and sales application and development manager since 1932.

N. R. Gibson (M'32) a vice-president of Niagara Hudson Power Corporation, Buffalo, N. Y., has been elected a director of the corporation. Doctor Gibson is also chief engineer of the Niagara Hudson companies.

Obituary • • •

Arthur William Berresford (A'94, M'06, F'14) retired managing director of the National Electrical Manufacturers Association, died May 30, 1941. He was born July 9, 1872, in Brooklyn, N. Y., and received the degrees of bachelor of science in electrical engineering from the Polytechnic Institute of Brooklyn, 1892, and mechanical engineer from Cornell University, 1893. During 1893 he was electrician for the Brooklyn City Railroad Company, and in 1894 joined the H. B. Coho Company, New York, N. Y., doing sales and installation work until 1895. After a year as designer for the Riker Electric Company, he took charge of the testing and design work of the Ward-Leonard Electric Company in 1896. In 1898, with two associates, he bought the assets of the Iron Clad Rheostat Company and organized the Iron Clad Resistance Company, which he sold in 1900 to the Cutler-Hammer Manufacturing Company of Milwaukee, Wis. He entered the engineering department of the company, was made superintendent in 1901, and in 1905 was made general manager and vice-president. He continued as vice-president for 18 years. In 1925 he became vice-president of the Nizer Corporation, Detroit, Mich., later part of the Electric Refrigeration Corporation. From 1929 until his retirement in 1934 he was manager of the National Electrical Manufacturers Association. During the first world war he was chairman of the general war service committee of the electrical manufacturing industry. He was a manager of the Institute from 1909 to 1912, and served as vice-president, 1912 to 1914, president, 1920–21, and as a committeeman. He was also a past president of the Electrical Manufacturers Club, the Associated Manufacturers of Electrical Supplies, and the American Engineering Council, and was a member of the Franklin Institute, The American Society of Mechanical Engineers, and the Society of Naval Architects and Marine Engineers. He received the Pheobe Hobson Fowler Medal of the American Society of Civil Engineers in 1930, for his work as president of The American Engineering Council.

Lorin Everett Imlay (A'00, M'03, F'13) retired director of statistics, Niagara Hudson Power Corporation, Buffalo, N. Y., died June 9, 1941. Born in Cumberland, Ohio, November 2, 1864, he received the degree of bachelor of civil engineering from Cornell College in 1888, and later received the degree of civil engineer from that college. He also did graduate work at the University of California. From 1892 to 1894 he was engineer for the San Antonio Light and Power Company, Pomona, Calif., and in 1894 became associated with the Westinghouse Electric and Manufacturing Company Pittsburgh, Pa., as construction engineer. In 1898 he was sent to Niagara Falls, N. Y., by the company. He became assistant superintendent of the Niagara Falls Power Company in 1902, and superintendent about 1908. In 1920 he was made operating engineer of the company, and also served as a manager. During 1920–21 he was an engineer for the superpower survey of the United States Geological Survey, New York, N. Y. Following this he served for several years as consulting engineer for the Niagara Falls Power Company in New York, N. Y., and about 1926 returned to Niagara Falls to do engineering work for the company. In 1927 he became a statis-

tical engineer for the Buffalo, Niagara, and Eastern Power Corporation, Buffalo, N. Y., and in 1930 joined the Niagara Hudson Power Corporation, Buffalo, as director of statistics. He retired in 1938. He was also a member of the American Electrochemical Society, the Canadian Electrical Association, and Phi Beta Kappa, and was the author of technical publications.

William W. Fraser (A'21, M'27) patent attorney of the patent law firm of Watson, Bristol, Johnson and Leavenworth, New York, N. Y., died March 31, 1941. Mr. Fraser was born October 28, 1884, in Las Vegas, N. Mex. He received the degrees of bachelor of arts, 1905, from New Windsor College, and bachelor of laws, 1911, and bachelor of science in electrical engineering, 1915, from George Washington University. He also did graduate work in mathematics and physics at Johns Hopkins University, 1905–06. From 1907 to 1916 he was an assistant examiner in the United States Patent Office, Washington, D. C. In 1916 he became assistant attorney in the patent department of the General Electric Company, Schenectady, N. Y. He joined the staff of attorneys for Duell, Warfield, and Duell, New York, N. Y., in 1921, and was put in charge of soliciting of electrical patents. In 1924 he became a member of the staff of attorneys for Mayer, Warfield, and Watson, New York, N. Y., in charge of soliciting of electrical patents. He was granted a license by the state of New York to practice as professional engineer in 1926. In the early 1930s he joined the firm of Watson, Bristol, Johnson and Leavenworth, and remained with that firm until his death. He was also a member of the American Electrochemical Society.

Glenn Harrison Barnard (M'26) general manager, Electro-Dynamic Works, Electric Boat Company, Bayonne, N. J., died May 6, 1941. Born January 21, 1889, in Hemlock, N. Y., Mr. Harrison received the degree of electrical engineer from Syracuse University in 1912. In 1912 he entered the testing department of the General Electric Company, Schenectady, and was later transferred to the consulting engineering department. From 1914 to 1916 he was in the marine control equipment section of the engineering department, and in 1916 was made senior civilian inspector for the bureau of engineering of the United States Navy Department, located at the General Electric Company, Schenectady, N. Y. From 1917 to 1919 he was on active duty as a lieutenant in the United States Naval Reserve Force, serving as a radio officer and an electrical officer. In 1919 he joined the Electro-Dynamic Company, a subsidiary of the Electric Boat Company, as sales engineer, and became general manager in 1931. He was also a member of the Society of Naval Architects and Marine Engineers, the American Society of Naval Engineers, and Tau Beta Pi.

Robert Henry Combs (A'13, M'18) president and general manager of the Prest-O-Lite Storage Battery Company, Ltd., Toronto, Ont., Canada, died April 25, 1941. Mr. Combs was born in Springfield, Mo., June 18, 1876. From 1893 to about 1900 he did electrical engineering work on lighting, power, and street railway projects, after which he did journalistic work until 1905, when he joined the Chicago Battery Company, Chicago, Ill. In 1907 he became consulting engineer for the Prest-O-Lite Company of Indianapolis, Ind., and in 1917 was transferred to Toronto, where he was made general manager and chief engineer of the Prest-O-Lite Company of Canada. He became president of the company about 1927. He was one of the organizers of the Toronto Radio Research Society, and a founder of the Canadian section of the Society of Automotive Engineers. He was secretary of the Royal Astronomical Society of Canada, and a member of the Society of Automotive Engineers and the Association of Professional Engineers of Ontario.

Erroll Warner Brandenstein (M'37) head of the railway electrification section of the General Electric Company's transportation engineering department at Erie, Pa., died May 20, 1941. Mr. Brandenstein was born March 11, 1896, in Cobleskill, N. Y., and received the degree of bachelor of science in electrical engineering from Union College in 1923. He served in the aviation branch of the United States Navy from 1917 to 1920. After completing the General Electric Company's test course at Schenectady, N. Y., in 1924, he entered the railway control division of the company as railway control proposition and requisition engineer. He was transferred to the railway motor division of the company in 1926, as proposition engineer, and to the transportation department in 1928 as application and commercial engineer. From 1931 to 1941 he represented the General Electric Company on the Pennsylvania Railroad electrification project. He had been head of the electrification section of the department since 1940.

Elias Schibsted Cornell (A'28, M'36) chief engineer of the Delta-Star Electric Company, Chicago, Ill., died May 14, 1941. Born January 21, 1900, in Oslo, Norway, Mr. Cornell received the degree of electrical engineer from the University of Zurich, Switzerland, 1923. After being employed for a short time as a draftsman for the Municipal Power Company, Oslo, he came to the United States in 1924 and became assistant to the electrical construction superintendent of the Ohio Power Company, Philo, Ohio, and later assistant to the chief electrician. In 1925 he became affiliated with Sargent and Lundy, Inc., Chicago, Ill., as a designer in the electrical division. He took a position with the Minnesota Power and Light Company as substation designer in 1926, and later in the same year joined the Delta-Star Electric Company, working in various departments until he was appointed assistant chief engineer in 1929. He became chief engineer in 1936.

Henry F. Sanville (A'01, M'12) consulting engineer, Philadelphia, Pa., died May 24, 1941. He was born July 11, 1872, in New York, N. Y., and studied electrical engineering at Columbia College. About 1893 he joined the General Electric Company, Lynn, Mass., as assistant engineer, and from about 1895 to 1897 engaged in electric railway construction in Pennsylvania, as assistant engineer and later as superintendent. After a year as a private school instructor he became associated with Elmer P. Morris, New York, N. Y., as engineer, and with the formation of the Morris Electric Company in 1899 was made secretary of that company. When the Splice and Terminal Company, New York, N. Y., was formed in 1900 he became secretary of this company also. In 1902 he went into private practice as consulting engineer in Philadelphia, and continued in this field until his death. He was one of the founders of the Philadelphia Section, AIEE, and was secretary of the section for 15 years.

David B. Budden (M'29) sales department, Benjamin Electric Manufacturing Company, New York, N. Y., died April 19, 1941. He was born December 11, 1885, in Brooklyn, N. Y. He was employed from 1906 to 1908 by the Safety Car Heating and Lighting Company, New York, N. Y., doing drafting and experimental and test work. In 1913 he became associated with the firm of Mailloux and Knox, consulting electrical engineers, New York, N. Y., as a draftsman and later in a supervisory capacity on various projects. In 1918 he became electrical engineer for the Thompson-Starrett Company, New York, N. Y., and was in charge of construction and operation of all electrical equipment in the United States Government Powder Plant at Nitro, W. Va. Since 1919 he had been with the eastern office at New York of the Benjamin Electric Manufacturing Company of Chicago, Ill., as electrical engineer and later as sales engineer, and also was on the technical advisory staff of the company.

Charles Ellsworth Hall (A'09) retired, formerly with the Northwestern Bell Telephone Company, Omaha, Nebr., died February 16, 1941. Mr. Hall was born September 26, 1861, in Florence Township, St. Joseph County, Mich. He joined the Iowa Telephone Company, Des Moines, Iowa, as exchange manager in 1884, and later became a special agent for the company. In 1887 he was made a superintendent, becoming general superintendent (1909) and general commercial superintendent (1911) for this company and other companies which later formed the Northwestern Bell Telephone Company. From 1913 to 1924 he was general manager for the Nebraska Telephone Company, Omaha, Nebr. (later part of the Northwestern Bell Telephone Company), and in 1924 became tax commissioner for the Northwestern Bell Telephone Company. He was made secretary of the company in 1929, and retired about 1930.

Peter Cornell Morganthaler (A'09) assistant to the manager of the Fort Wayne, Ind., works of the General Electric Company, died March 29, 1941. He was born August 28, 1879, in Fort Wayne, Ind., and joined the Fort Wayne works in 1897, as a student in the engineering course conducted by the company. In 1899 he entered the meter department, where he did general sales work until he was transferred to the office of the meter sales department in 1902.

He became engineer in the meter department in 1904, later becoming managing engineer of that department, and in 1926 was made assistant to the manager of the works.

James Edward Blake Phelps (M'29) manager and electrical engineer, Sarnia Hydro-Electric System, Sarnia, Ont., Canada, died April 24, 1941. He was born in Springford, Ont., October 20, 1873. From 1900 to 1916 he was chief engineer and electrical superintendent for the Sarnia Gas and Electric Light Company. In 1916 he became general manager and electrical engineer for its successor, the Sarnia Hydro-Electric System, a position which he held until his death. He was a past president of the Association of Municipal Electrical Utilities of Ontario.

Carl LeRoy Dillman (A'36) resident operator of the terminal substation of the Idaho Power Company, Caldwell, Idaho, died April 27, 1941. Mr. Dillman was born August 8, 1913, in Glencoe, Okla. He received the degree of bachelor of science, 1935, from Oregon State College. From 1935 to 1939 he was manager of the electrical department of the Dillman Hardware Company, Burns, Ore. In 1939 he became resident operator of the terminal substation of the Idaho Power Company at Caldwell, which position he held until his death.

Membership • •

Recommended for Transfer

The board of examiners, at its meeting on June 12, 1941, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Holslag, C. J., president, Electric Arc, Inc., Newark, N. J.

1 to Grade of Fellow

To Grade of Member

Barnett, H. G., central station engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Byler, A. E., consulting electrical engineer, Los Angeles, Calif.

Carson, H. E., district engineer, New England Power Service Company, Providence, R. I.

Collison, G. C., proprietor, Collison Battery Supply Company, Washington, D. C.

Dagnall, C. H., member of technical staff, Bell Telephone Laboratories Inc., New York, N. Y.

DeBoer, D. J., chief electrical engineer, Loup River Public Power District, Columbus, Nebr.

Finkenauer, F. J., Chrysler Corporation, Highland Park, Mich.

Gehrke, J. W., distribution engineer, Dayton Power and Light Company, Dayton, Ohio.

Hess, W. F., associate professor in metallurgical engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

Hoadley, G. B., assistant professor of electrical engineering, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Jennings, O. S., section engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Klitten, A. H., engineer, Westinghouse Electric and Manufacturing Company, Sharon, Pa.

Ludwig, L. R., electrical engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Mertz, R. H., general test engineer, Detroit Edison Company, Detroit, Mich.

Owler, D. S., first vice-president and manager, Fall River Electric Light Company, Fall River, Mass.

Packer, F. W., transmission engineer, Pennsylvania Power and Light Company, Allentown, Pa.

Reeve, H. E., assistant superintendent, Des Moines Electric Light Company, Des Moines, Iowa.

Setterstrom, R. C., industrial engineer, The Montana Power Company, Butte, Mont.

Vaughan, H. R., district engineer, Westinghouse Electric and Manufacturing Company, St. Louis, Mo.

19 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical Districts. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before July 31, 1941, or September 30, 1941 if the applicant resides outside of the United States or Canada.

United States and Canada

1. NORTH EASTERN

Benham, F. A. (Member, re-election), New England Telephone and Telegraph Company, Boston, Mass.

Bennett, G. T., Central New York Power Corporation, Utica, N. Y.

Costello, J. J., Jr., J. J. Costello Company, Boston, Mass.

Crout, P. D. (Member), Massachusetts Institute of Technology, Cambridge, Mass.

Daly, D., Blackstone Valley Gas and Electric Company, Pawtucket, R. I.

Devereaux, H. H., Central New York Power Corporation, Watertown, N. Y.

Dorsa, S. C., General Electric Company, Schenectady, N. Y.

Gaffney, D. A., Central New York Power Corporation, Utica, N. Y.

Geiger, L. J., Jr., General Electric Company, Schenectady, N. Y.

Harding, R. M., Central New York Power Corporation, Utica, N. Y.

2. MIDDLE EASTERN

Anseaume, H. T., Robert P. Schoenijahn, Consulting Engineer, Wilmington, Delaware.

Barnes, G. C. (Member), West Virginia Engineering Company, Williamson, W. Va.

Green, C. E. J., Leeds and Northrup Company, Pittsburgh, Pa.

Hessin, M. R., American Telephone and Telegraph Company, Cincinnati, Ohio.

Holzer, O. E., General Electric Company, Columbus, Ohio.

Horne, I. J., Allis-Chalmers Manufacturing Company, Pittsburgh, Pa.

Kees, F. G., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Read, E. K. (Member re-election), Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Rundlett, T. L., Westinghouse Electric and Manufacturing Company, Sharon, Pa.

Schwartz, C. U., American Telephone and Telegraph Company, Cincinnati, Ohio.

Vaitsen, G. S. (Member), United States Maritime Commission, Washington, D. C.

Watkins, L., Chesapeake and Potomac Telephone Company, Washington, D. C.

Zimsky, J. J., Pennsylvania Transformer Company, Pittsburgh, Pa.

3. NEW YORK CITY

Breier, J. E., United States Rubber Company, Passaic, N. J.

Budd, H. L. (Member), Merritt-Chapman and Scott, New York, N. Y.

D'Heedene, A. R., Bell Telephone Laboratories, Incorporated, New York, N. Y.

Gallogly, F. J., United States Government, Navy Department, Arma Corporation, Brooklyn, N. Y.

Gendreau, R. C., Gibbs and Cox, Incorporated, New York, N. Y.

Siciari, V., Federal Shipbuilding and Drydock Company, New York, N. Y.

Spitz, F., Charles F. Zweifel and Company, Incorporated, New York, N. Y.

Vann, A. M., Jr., Underwriters' Laboratories, Incorporated, New York, N. Y.

Van Rijn, K. C. (Member), Philips Export Corporation, New York, N. Y.

4. SOUTHERN

Broom, C. M., Florida Power and Light Company, Lake City, Fla.

Carter, H. R., Jr., Civil Aeronautics Administration, c/o Regional Manager, Atlanta, Ga.

Coleman, D. T. (Member), South Carolina Power Company, Charleston, S. C.

Pouche, W. L., W. Horace Williams Company, Camp Polk, Leesville, La.

Lacefield, W. R., Reynolds Metal Company, Florence, Alabama.

Olson, M. P., Tennessee Valley Authority, Chattanooga, Tenn.

Wachowiak, M. M., Solvay Process Company, Hopewell, Va.

Wolfenson, S. J., Tennessee Valley Authority, Wilson Dam, Ala.

5. GREAT LAKES

Fenwick, J. E., John E. Fast and Company, Chicago, Ill.

Galloway, E. W. (Member), Alvord, Burdick & Howson, Chicago, Illinois.

Hampton, W. O. (Member re-election), Delta-Star Electric Company, Chicago, Illinois.

Hanks, C. C., Illinois Iowa Power Company, Hillsboro, Ill.

Lewin, W. A., General Electric Company, Chicago, Ill.

McNary, V., Commonwealth Edison Company, Pekin, Illinois.

Schaefer, C. A., Square D Company, Milwaukee, Wisconsin.

Storm, H. F., Chicago Flexible Shaft Company, Chicago, Ill.

Waters, H. R., Cutler-Hammer, Incorporated, Milwaukee, Wisconsin.

7. SOUTH WEST

Lancaster, R. A., Consolidated Steel Corporation, Limited, Orange, Texas.

Pillet, J. P., Texas Electric Service Company, Fort Worth, Texas.

Warren, C. T., Jr., Consolidated Steel Corporation, Limited, Orange, Texas.

Yoe, C., Wichita High School North, Wichita, Kansas.

8. PACIFIC

Broun, W. F. (Member), California Shipbuilding Corporation, Wilmington, Calif.

Brown, N. F., Southern California Edison Company, Limited, Los Angeles, Calif.

Doyle, W. T., United States Navy Yard, Mare Island, Calif.

Jackling, D. C. (Member), Kennecott Copper Corporation, San Francisco, Calif.

9. NORTH WEST

Davis, C. E., Mountain States Telephone and Telegraph Company, Butte, Mont.

Fitzstephens, W., Montana Power Company, Butte.

Harris, C. E., Washington Water Power Company, Spokane, Wash.

Lauer, C. O., The Gardiner Electric Light and Water Company, Gardiner, Mont.

May, L. W., Mountain States Telephone and Telegraph Company, Helena, Mont.

Sickler, A. (Member), Bonneville Power Administration, Portland, Ore.

Smith, T. C. (Member), Bonneville Power Administration, Portland, Ore.

Spaulding, L. R., Northwestern Electric Company, Portland, Ore.

10. CANADA

Cockerell, R. L., Light and Power Department, City of Regina, Saskatchewan.

Doerr, C. F., Western Dominion Coal Mines, Limited, Bienfait, Saskatchewan.

Mole, H. W., Norton Company, Chippawa, Ontario.

Total, United States and Canada, 68

Elsewhere

Abell, R. H. (Member), Central Electricity Board, Horsley Towers, East Horsley, Surrey, England.

Khan, S. A. Public Works Department, Electricity Branch, Punjab, India.

Webb, T. F., M. V. Macdhui, Burns Philip and Company, Sydney, Australia.

Wood, F. E. (Member), Minas de Matahambre, Matahambre, Pinar del Rio, Cuba.

Total, elsewhere, 4

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the addresses as they now appear on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Bedford, P. L., 625 W. Arlington St., Chicago, Ill.

Bluethental, Herbert, Jr., 902 Concord Ave., Wilmington, Del.

Brown, Charles A., 14631 Valerio St., Van Nuys, Calif.

Clinchard, W. C., Jr., Fajardo Sugar Co., Fajardo, P. R.

Doenges, Franklin G., 3360 N. Meridian St., Indianapolis, Ind.

Dusenbury, Charles, 6744 Penna Ave., Pittsburgh, Pa.

Griffin, E. E., 2619–25 Santa Fe Ave., Los Angeles, Calif.

Kaylin, Rubin Robert, 930 Lenox Road, Brooklyn, N. Y.

Lacerte, W. J., 129 N. Walnut St., East Orange, N. J.

Lancaster, Eugene L., Jr., 646 N. Congress, Jackson, Miss.

Martinez, Joseph D., 550 Florence Ave., Downey, Calif.

Radcliffe, J. H., 334 Reid St., Peterboro, Ont., Can.

Simpson, J. L., Jr., 1040 Eden Ave., S.E., Atlanta, Ga.

Warren, Roy Everett, 3360 Meridian St., Indianapolis, Ind.

14 Addresses Wanted

Of Current Interest

National Defense

More Subcontracting Urged

When the United States embarked on its "all out" National Defense Program last year, the first problem was to expand as rapidly as possible the nation's manufacturing capacity. This involved the construction of hundreds of new manufacturing plants and facilities, expansion of many existing plants, and production of new machinery for both. The first period of plant expansion and tooling is rapidly nearing completion and quantity production is getting under way on a greatly expanded basis.

By far the great bulk of production will be accomplished in private manufacturing plants. Some 14,000 primary contracts have now been let; to attain speed, these contracts in general have been placed with concerns that can handle the whole contract. To speed production still further, subcontracts have been let by the primary contractors, totalling between 50,000 and 60,000. Convinced that subcontracting is one important answer to the demand for expedited production, officials of the defense contract service are urging an extension of this practice, and there is some talk of requiring recipients of primary contracts to subcontract part of the work.

PENNSYLVANIA'S POOLING PLAN

To speed Defense production in the industries of the Commonwealth of Pennsylvania, the State Department of Commerce has promoted the creation of a state-wide "pooling plan". In brief, the plan involves maintaining a running inventory of current idle hours of machines and men in operating industrial plants in the area covered by the pool. These pools are now in operation in 36 principal industrial areas throughout the state. By exchanging idle plant and machine inventories with other pools, plant managers in immediate need of increased production can ascertain promptly where such equipment is available anywhere in the state and can farm out the needed work to subcontractors.

The success of the pooling plan had been demonstrated during the fall of 1940 in York, Pa., which had organized the first pool as an experiment started by industrial leaders in that city. The pooling plan also aids in subcontracting from industrial firms in various parts of the country seeking to sublet armament work to Pennsylvania plants.

PRODUCTION CLINIC AT BUFFALO, N. Y.

The first large scale "Defense Production Clinic" brought together prime contractors and potential subcontractors in various parts of New York State at Buffalo, N. Y., May 15. In addition, the Clinic was attended by representatives of ten governmental agencies concerned with Defense production. During the all-day clinic, the prime contractors had opportunity to contact directly the representatives of 94 potential subcontractors, and in several instances actual subcontracts were let.

Because of the success of this first clinic, the State Commerce Division has decided to hold additional clinics, and the Erie County Defense group plans to hold an augmented clinic in Buffalo later.

Electric Power

Out of the current welter of words concerning the shortage of electric power for the National Defense Program, either impending or actual, have emerged a few facts. Skyrocketing production of aluminum in the southeastern states plus the current drought have created a situation where the available power supply may curtail the desired output of this vital metal. New generating capacity either already under construction or on order for both private-utility and government-owned plants is expected to go a long way toward obviating future shortages.

Rainfall in the southeastern states has been only about 50 per cent of normal this year; as a result, the flow of rivers in that area is less than in any year of record. Consequently the reservoirs of all hydroelectric plants in that area, including the TVA plants and the many privately owned plants, are at dangerously low levels. With production expanding not only in the heavy-power-consuming aluminum industry but also in the ferroalloy steel and various chemical industries in the area a serious power shortage may result unless heavier rains come soon.

To deal with the threatened shortage, coordination of governmental and private power supplies on a large scale has been undertaken. A total of 18 power systems in 17 states have pooled their power resources with those of the Tennessee Valley Authority. In addition, steam stand-by stations have been placed in regular operation, as well as reserve generating units, and interconnecting lines are being utilized to transmit power into the area from adjacent areas. Other measures include restriction of power consumption by nondefense industries, restriction of display lighting, and adoption of daylight-saving time by some communities. As a result of this co-operative effort it is hoped that the present emergency situation may be met without serious power shortages to essential Defense industries.

PLANT EXPANSION PLANS FOR 1941–42

Expansion of generating capacity in publicly and privately owned plants already planned for 1941 and 1942 totals more than $7\frac{1}{2}$ million kilowatts according to a report by President C. W. Kellogg (A'19, M'23) of Edison Electric Institute, presented at the recent annual meeting of that organization. In addition, 1,046,000 kw expansion already is planned for 1943 and 668,000 kw for 1944; these figures are expected to increase markedly before the programs for those years are completed. A total of 4,150,000 kw is expected to be put into service in 1941 and 3,430,000 kw in 1942.

In spite of the magnitude of this expansion program, the Federal Power Commission in the eighth of its reports on "Electric Power Requirements and Supply in the United States" predicts a possible deficiency of 1,400,000 kw as a result of the expansion of the Defense Program. Conclusions reached by the Commission on the basis of that report "suggest strongly that unless orders are placed immediately for large amounts of additional capacity for 1943, serious shortages will develop in that year, and in subsequent years if the emergency continues. The importance of placing orders immediately is accentuated by the fact that, under present conditions, from two to three years are required to complete the manufacture and installation of generating facilities, with every indication that even longer periods may be required as the Defense Program expands.

"The situation has definitely become more critical since last December when the report indicated that approximately one-half of the power supply areas would have sufficient capacity to supply the anticipated demands for the remainder of 1941 without encroaching on reserves or obtaining additional capacity through interconnections. It is becoming apparent that further increases in the tempo of the defense effort will be felt in many areas before the end of the year."

CRESTA AND PULGA PLANTS AUTHORIZED

The Federal Power Commission has reauthorized the issuance of a license to the Pacific Gas and Electric Company for the construction of the Cresta and Pulga power plants on the North Fork of the Feather River. The Commission states that "its surveys conducted at the direction of the President for the purpose of reporting upon defense requirements during the present national emergency definitely indicate: 'that assurance against shortage of power for California's share of the Defense Program will require not only the expeditious construction of the Cresta and Pulga power plants, but also the earliest possible completion of the Central Valley Project, including the proposed steam plant at Antioch'". The Commission originally authorized issuance of a license for these plants on February 19, as announced in an earlier issue (*April '41 EE, p. 188–9*). At a later hearing, the Commission reversed this authorization, pending further study. In reapproving these projects, the Commission denied a petition on the part of the company to extend the license period from 35 to 50 years.

MORE GENERATORS FOR BONNEVILLE

An order recently was placed with the General Electric Company, Schenectady, N. Y., for the last four of the ten generators

which will complete the 576,000-kva hydroelectric development at Bonneville, Oregon. Each unit will be rated 60,000 kva, and all are expected to be installed by the end of 1943.

Defense Planning for Period of Years Urged by Reed

Nondefense industries must plan for "a period not of months but of years" to get along with much less than their requirements in a long list of strategic materials, Philip D. Reed, chairman of the board of the General Electric Company, said at the recent annual meeting of the National Industrial Conference Board at New York, N. Y. Mr. Reed, who for three months has been senior consultant to the director of priorities of the Office of Production Management in Washington, said he was expressing "a few personal observations on several points that must be considered in charting the course of any business".

Prime emphasis will be placed on military products for five or more years, he said, and added that "the sooner we accept the fact, for purposes of planning, that we face a long period of enormous production for defense, with a consequent shortage, rationing, and allocation of strategic materials, the more quickly will nondefense industries adjust themselves to the new conditions and undertake the great task of maintaining maximum production for civilian needs without interference with defense output".

"From every standpoint—social, economic, and political—we must put and keep all of America at work," Mr. Reed said. He suggested "the redesigning of peacetime products wherever possible, and where impossible the preparation for defense manufacture" to prevent shutdowns and unemployment.

Mr. Reed predicted that engineers, chemists, and designers will develop new products to help absorb the increased purchasing power, allay inflationary pressures, support our standard of living, and keep the country at work. One of the benefits of a larger national income, he said, would be an increased ability to pay for a large part of the Defense Program as we go.

The post-war decade will resemble neither the 1920's nor the 1930's, said Mr. Reed, and "I suspect that the war will advance by several decades the 20th-century trend away from laissez faire and toward economic integration and industry-wide planning under government supervision."

He summed up the following points to be expected in the future:

1. A mature, consolidated, national labor organization, led by able and understanding men, who will negotiate all questions pertaining to wages, hours, and conditions of work, with business leaders acting in concert through associations of employers on an industry basis.

2. A continuation of the trend toward centralized control of money and credit.

3. Large and gradually declining government spending for previously planned and generally desirable public projects, for several years after the war, in order to cushion the devastating effect of an almost vertically declining demand for armaments.

4. Great emphasis placed on production and a deep determination to take whatever steps are necessary, however drastic, to avoid a recurrence of mass unemployment. To this end we may expect to see the government gradually relinquishing its ownership of Defense plant facilities on terms and conditions that will provide the purchaser with a strong incentive to maintain production and employment.

5. Subject to these changes, a sincere attempt to preserve the elements and incentives of the enterprise system.

"Whether under these conditions, and with profit margins generally lower than in the past, there will be enough confidence to create a broad flow of private savings into new and existing enterprises will be the factor that determines whether more drastic experiments in government borrowing and spending will be resorted to."

MEN WANTED

For the British Civilian Technical Corps

The following announcement was read at the annual AIEE summer convention banquet June 19, 1941, by General Chairman McHenry.

We believe that members of the Institute will be interested in the recent announcement by Air Commander Pirie, air attache at British Embassy, covering the establishment of the Civilian Technical Corps.

According to the announcement, in agreement with the Government of the United States the British Government have completed plans for receiving applications from volunteer American technical craftsmen for paid noncombatant employment abroad in the Civilian Technical Corps.

Among those most urgently required are men to maintain the new air-defense weapons known as "radiolocators", now in active use against enemy air fleets all over the British Isles. "Radiolocators" are an essential part of the protection of civilians from bombing attacks.

Detailed information and booklets can be had from the British Consulate General, 25 Broadway, New York City.

New Plant Construction

Some recently reported plant-expansion programs related to the National Defense Program are the following:

Vega Airplane Company, Burbank, Calif. The new $7,000,000 factory of this company, which will provide 1,256,491 square feet of working space, will be lighted by fluorescent lamps throughout, utilizing a total of more than 36,500 tubes; the total lighting load is estimated at nearly 1,500 kw. This is said to be the largest installation of fluorescent lighting to date and some of the units have the highest mounting in existence, being 40 feet above the floor at some points.

Douglas Aircraft Company, Inc., Long Beach, Calif. The new $11,000,000 "blackout" plant of this company consists of 11 windowless buildings. The entire plant will be air conditioned by 35 complete Westinghouse air conditioning systems, having a combined capacity of 1,400,000 cubic feet of air per minute. To save floor space equipment is being installed in the roof trusses. This plant will be lighted by approximately 10,000 400-watt mercury-vapor lamps and 15,000 fluorescent lamps; lighting load will total approximately 5,000 kw. Illumination on a working plane 30 inches above the floor will average approximately 30 foot-candles. Construction is expected to be completed by midsummer.

Parsons Electric Company, Chicago, Ill. To take care of United States Navy contracts and a growing industrial demand for time-control instruments, this company has moved its manufacturing facilities from Manitowoc to Two Rivers, Wis. In the new location the company will occupy a building having 25,000 square feet of floor space—double the area of the former plant.

E. I. du Pont de Nemours and Company. A new neoprene synthetic rubber plant is being built at Louisville, Ky., by this company. It will have a capacity of 10,000 long tons per year, which exceeds the present total combined production of all synthetic rubber.

Positions to Be Filled Through Civil Service Examination

Notice of the following positions, which will be filled through civil service examinations, is published here as a service to members of the Institute. Application forms and full information as to requirements for examinations may be obtained from the secretary of the Board of United States Civil Service Examiners at any first- or second-class post office, or from the United States Civil Service Commission, Washington, D. C.

Inspector of engineering materials, Navy Department. Positions pay from $1,620 to $2,600 a year and persons may qualify in the following optional branches: steel hulls, mechanical, electrical, and radio. Although experience in the inspection or testing of engineering materials in the optional branches is required, applicants for the junior, assistant, and associate grades will not be limited to any specific optional branch. Substitution of mechanical or other related types of experience, or of appropriate education, may be made for a part—or for some grades, all—of this inspectional experience. Except for the positions of junior inspector for which the maximum age is 35 years, applicants must not have passed their 65th birthday.

Inspector of ship construction, Navy Department. Positions pay from $2,000 to $2,600 a year. There are four optional branches of inspection: Electrical, mechanical, steel hulls, and wood hulls. Experience in testing or inspection construction or installation work is required, but for a part—or for some positions, all—of this experience applicants may substitute mechanical or other related types of experience, appropriate education, or possession of a marine engineer's license. The maximum age limit is 65 years. The duties to be performed by inspectors of engineering materials and ship construction involve testing and inspecting the type of marine construction, or construction materials, indicated by the optional branches. Inspectors will also read drawings and interpret specifications, as well as make inspection reports and conduct correspondence.

Inspectors of naval ordnance, guns, munitions, and optical instruments, Bureau of Ordnance, Navy Department. No written examinations are being given, but applicants are being rated on the basis of education, training, and experience as shown on the applications. Anyone under 65 years of age qualified in any of the several fields connected with the work is eligible to apply for these positions,

Employee-training programs already in operation among the subsidiaries of United States Steel Corporation have been intensified to provide skilled workers for the National Defense effort. Here are shown four apprentices receiving instruction in welding at the Ambridge, Pa., plant of the American Bridge Corporation

which carry salaries ranging from $1,620 to $2,600 a year for the various grades. To qualify for either of the two higher grades, considerable experience must be shown in one of the four specific branches of naval ordnance: optical and fire control instruments, naval guns and accessories, munitions, or ordnance units. In the lower grades, $1,620, $1,800 and $2,000 a year, an applicant may qualify on education alone or by showing the proper amount of experience in such varied fields as inspection of ordnance materials; experience in one of the skilled trades connected with optical or fire-control instruments; college study in engineering, physics, or metallurgy; experience in adjusting or setting-up automatic screw machines or turret lathes; inspection of machine tools, tools, gages, instruments; experience in tool or gage designing; experience in the assembly of machine tools, printing presses, speedometers, optical or fire-control instruments, or similar delicate and sensitive electrical or mechanical precision instruments, or other intricate hydraulically operated or controlled instruments; or completion of appropriate National Defense training courses approved by the Office of Education.

"Vision in Defense Industry." A forum on the relation of efficient vision and adequate lighting to safety and production efficiency in Defense industry is being held July 3 at Atlantic City, N. J., under auspices of the American Optometric Association. Among the scheduled addresses are the following:

LIGHTING—OLD AND NEW, **Samuel G. Hibben** (A'34), director of applied lighting, Westinghouse Electric and Manufacturing Company.

APPLICATION OF MODERN LIGHTING IN INDUSTRY, **H. L. Logan** (A'19, M'28), managing engineer, Controllens division, Holophane Company, Inc.

LIGHT, VISION AND SEEING IN INDUSTRY, **Matthew Luckiesh** (A'11, F'10), director, and **Frank K. Moss**, physicist, lighting research laboratory, General Electric Company.

Fifth Unit at the Vancouver Aluminum Plant. Capacity of the Vancouver, Wash., plant of the Aluminum Company of America was increased to more than 150,000,000 pounds annually, when the fifth production unit was placed in operation May 28. This brings to completion the construction project begun less than 15 months ago when the site now occupied by the new works was a cow pasture. The first unit went into operation last September, less than six months after first concrete was poured; a second unit was completed in September, a third in March, and the fourth in April. Power is supplied by the Bonneville hydroelectric plant, contracts having been signed for a total of 162,500 kw.

Industry • • • •

Report on Industrial Research Issued by Government Planning Board

"Industrial Research", the second of a series of reports on "Research—a National Resource", has been issued by the National Resources Planning Board. The report was prepared under the direction of the National Academy of Sciences and the National Research Council, with a committee of the latter organization in charge of the survey.

Research conducted by American industry, described as "a major national resource", employs more than 70,000 workers in over 2,200 laboratories, at an estimated annual cost of $200,000,000, the survey found. The report shows the United States to be virtually independent of foreign sources for adequate apparatus and facilities for laboratory research.

Finding that research is possible for all industrial units, large or small, the report notes that its distribution seems to depend upon management policy. "Research is most active in companies utilizing technically trained men in design, production, or sales activity," it points out. While industry looks to the universities for its technically trained men and for advances on the frontiers of science, it is observed that such advances are not infrequently made in the course of research for immediate commercial objectives. The report calls attention to the opportunity for universities to establish a comprehensive curriculum in applied mathematics, to make even more valuable the work now being done by the few in that field.

The chemical industry was found to lead in percentage of income devoted to research, which varies widely among industries. Several large industries were found lacking in research facilities, and the committee recommended that leaders of these industries associate themselves with the NRC investigating facilities for undertaking it. Consultation of the sources of co-operation listed was recommended to companies not now conducting research. The committee expressed the belief that a liberal policy in regard to publication of findings had proved profitable to the industries adopting it. Pointing out that organized labor as well as informed industry favors research, the report suggests a co-operative study of fatigue and similar problems by labor and industry.

Encouragement of research by Government is strongly urged. "In order that findings of Government laboratories generally be made readily and continuously available to industry, it is recommended that Government bureaus receiving appropriations for scientific work be less restricted than at present in allowances for representation at technical meetings, for publication of findings, and in general for co-operation with industrial technical workers." The report also recommends increased support to the National Bureau of Standards for standards research and publication of findings; provision by Government for the publication and distribution of abstracts of scientific literature, now supported by technical societies; extension and revision of the International Critical Tables of Numerical Data, Physics, Chemistry, and Technology, published in 1926 under the auspices of the International Research Council and the National Academy of Sciences. Such restrictive policies by Government as the capitalization of research expenditures for tax purposes are opposed as contrary to the public interest. Relations between research men in Government and in industry were declared to be in general close and cordial.

The contents of the report include detailed studies on research in the national economy, which contains a section on careers in research; examples of research in industry; location and extent of industrial research activity in the United States; research abroad; and studies of men in research, covering chemistry; physics; biology; industrial mathematics; metallurgy; chemical, electrical, and mechanical engineering, and border-line fields.

The report was prepared under the direction of Raymond Stevens, vice-president, Arthur D. Little, Inc., Cambridge, Mass. Among the members of the committee on survey of research in industry which sponsored the survey are the following Institute members: O. E. Buckley (M'19, F'29) president, Bell Telephone Laboratories, New York, N. Y.; W. D. Coolidge (A'10, M'34) vice-president and director of research, General Electric Company, Schenectady, N. Y.; Maurice Holland (A'23, M'30), director, division of engineering and industrial research, National Research Council, New York, N. Y.; F. B. Jewett (A'03, F'12) vice-president, American Telephone and Telegraph Company, and president National Academy of Sciences. The article on "Industrial Research in the Field of Electrical Engineering" in the section on "Men in Research" was prepared by D. C. Jackson (A'87, F'12) professor emeritus of electrical engineering, Massachusetts Institute of Technology, Cambridge, and H. B. Richmond (A'19, F'40) treasurer, General Radio Company, Cambridge, Mass.

Copies of the report may be obtained from

the Superintendent of Documents, Washington, D. C., at $1.00 each.

The first of the series of reports on research being issued by the National Resources Planning Board with the co-operation of scientific councils and committees was "Relation of the Federal Government to Research", published in 1938 (50¢). Further studies are expected to deal with research by business organizations, colleges and universities, and state and municipal governments. Recent publications of the National Resources Planning Board also include "Development of Resources and Stabilization of Employment in the United States—Part I, The Federal Program for National Development" (25¢); "Land Classification in the United States" (60¢); and "Public Land Acquisition in a National Land Use Program—Part II, Urban Lands" (20¢).

Modern Plastics Competition. *Modern Plastics Magazine* has announced the sixth annual Modern Plastics Competition, for which any plastic-using firms, designers, molders, laminators, fabricators, materials suppliers, machinery and die makers are invited to submit entries before September 8, 1941, to the headquarters of the magazine, 122 East 42d Street, New York, N. Y. Any plastic object or product which has been designed or put on the market since September 1, 1940, is eligible Articles will be classified in one of 16 groups, among which is military and defense articles. Prize winners will be announced in the November 1941 issue of *Modern Plastics Magazine*.

Coffin Award to Wisconsin Company. The Wisconsin Public Service Corporation received the Charles A. Coffin Award for 1940, which was presented at the recent convention of the Edison Electric Institute at Buffalo, N. Y. The award, consisting of a gold medal and $1,000 for the employees' benefit fund, is bestowed annually on a utility company for an outstanding record in the development of electric light and power for the convenience of the public and the benefit of the industry. The Charles A. Coffin Foundation, which makes the award, was founded in 1922 by the General Electric Company in honor of its founder and first president.

Other Societies • • •

Committees Set Up by NRC to Advise South Americans

A South American committee, divided into subcommittees on banking, iron and steel, petroleum, transportation, and research and standardization, has been established by the National Research Council as a result of the recent tour of South American countries made by 21 executives under its sponsorship. At the request of several South American governments, the Council states, the members of the tour have been organized as a permanent advisory committee, divided as already mentioned, to make recommendations regarding the selection of United States laboratories, engineers, and other technicians upon specific request from government and industrial agencies. Maurice Holland (A'23, M'30) director of NRC's division of engineering and industrial research is a member of the subcommittee on research and standards.

A report of the tour, which observed industrial progress in Colombia, Peru, Argentina, Chile, Uruguay, and Brazil, is to be submitted to the United States Department of Commerce.

IRE Appoints College Representatives

"Recognizing that a steadily increasing proportion of the young engineers entering the radio industry have been trained in universities", the Institute of Radio Engineers has inaugurated a program to improve relations with universities and students. Teachers of communication who are members of the Institute are being appointed Institute representatives in their respective schools, for the purpose of encouraging student membership through meetings and other activities. Student membership in the IRE, which increased nearly two-fifths as a result of an informal campaign during 1939 and 1940, is expected to show greater gains with the new program. Representatives have been appointed in about 65 institutions and others are being added as students show interest in the IRE. Another aspect of the program is a campaign to encourage more teachers of radio and communication to join the IRE.

NRC Issues Report on Chemistry in Insulation Research

"Contributions of the Chemist to Insulation Research", a review of chemical advancements in the field of electrical insulation from June 1939 to January 1941, has been prepared and issued by the committee on chemistry of the National Research Council Conference on Electrical Insulation.

Members of the committee have surveyed the literature in their respective fields and reviewed and summarized the more important developments. The various reports with their authors, are:

Chemical Progress in Insulating Oil, H. A. Ambrose

Recent Progress in Studies of Anomalous Dispersion Phenomena, O. M. Arnold

Chemical Developments in the Field of Insulation, A. G. Assaf

Review of Progress in Rubber Insulation, S. T. Blake

Review of Synthetic Plastic Electrical Insulation in 1940, H. H. Bundy and R. C. Reinhardt

Insulating Paper, G. T. Kohman

Copies of the review may be obtained from R. H. Evans, chairman, committee on chemistry, Consolidated Edison Company of New York, Inc., 55 Johnson Street, Brooklyn, N. Y.

Help Needed for British Electrical Engineers

The British War Relief Society has appealed to trade and professional organizations in the United States for help to their colleagues in Great Britain. Pointing out that thousands of business and professional people have been killed or wounded, as well as suffering the loss of their possessions, and that they and their families are in urgent need of help, the Society has set up a special fund to which American organizations or their members may contribute, with the assurance that contributions will be referred to the recognized organizations of their business or profession in England.

Members of American organizations are invited to visit the headquarters of the British War Relief Society and inspect the relief equipment, clothing, and other articles contributed to war sufferers. Contributions in United States funds may be used to send articles from these stocks, or paid in English funds through organizations in Great Britain. AIEE members interested should write directly to the British War Relief Society at 730 Fifth Avenue, New York, N. Y., or at its headquarters in other principal cities of the United States.

Future Meetings of Other Societies

American Chemical Society. Annual meeting, September 8–12, 1941, Atlantic City, N. J.

American Mathematical Society. 47th summer meeting, September 2–6, 1941, Chicago, Ill.

American Society of Civil Engineers. Annual convention, July 23–25, 1941, San Diego, Calif.

Fall meeting, October 15–17, 1941, San Diego, Calif.

American Society of Mechanical Engineers. Fall meeting, October 12–15, 1941, Louisville, Ky.

Association of Iron and Steel Engineers. Annual convention, September 23–26, 1941, Cleveland, O.

Illuminating Engineering Society. Convention, September 22–25, 1941, Atlanta, Ga.

National Metal Congress. October 20–22, 1941, Philadelphia, Pa.

National Safety Council. 30th National Safety Congress and Exposition, October 6–10, 1941, Chicago, Ill.

Society of Automotive Engineers. National Aircraft production meeting, October 30, 31, 1941, Los Angeles, Calif.

Education • • •

Columbia Offers Electrochemistry Course. Recognizing the increasing demand for electrical-engineering graduates in the electrochemical industry, the department of electrical engineering at Columbia University, New York, N. Y., is offering an electrochemical power option. The course, prepared with the assistance of the departments of chemical engineering and of metallurgy, is intended to afford training specifically for electrical engineers anticipating employment in the electrochemical and electrometallurgical industries.

Columbia Appoints Finch Associate Dean. James Kip Finch, Renwick Professor of Civil Engineering at Columbia University has been appointed to the position of associate dean of the faculty of engineering.

He will take over the administrative duties of Joseph W. Barker (M'26, F'30) dean of the engineering school, who will be on leave until September, the announcement stated. Professor Finch has been a member of the Columbia staff for 31 years. In 1930 he was appointed Renwick Professor, and in 1932 was made head of the civil-engineering department.

Iowa State Awards Marston Medal. H. J. Brunnier, consulting structural engineer, San Francisco, Calif., was awarded the 1941 Marston Medal, highest honor of the engineering division of Iowa State College. Mr. Brunnier is a civil engineering graduate of Iowa State College of the Class of 1904. He is the fourth recipient of the award.

T. U. Taylor Dies. Thomas Ulvan Taylor, dean emeritus of the college of engineering, University of Texas, Austin, died May 28, 1941. Born in Parker County, Texas, January 2, 1858, he received the degrees of civil engineer, University of Virginia, 1883, and master of civil engineering, Cornell University, 1895. He became professor of civil engineering at the University of Texas in 1888 and dean of engineering in 1906. He retired in 1936. He was made an honorary member of the American Society of Civil Engineers in 1940.

Library

OPERATED jointly by the AIEE and the other founder societies, the Engineering Societies Library, 29 West 39th Street, New York, N. Y., offers a wide variety of services to members all over the world. Information about these services may be obtained on inquiry to the director.

Bibliography on Induction Heat Treatment

The Engineering Societies Library has prepared a list of selected references on the heat treatment of metals by induction heating. Forty papers of importance are listed, selected from domestic and foreign periodicals, dealing with the metallurgical problems involved, the design of heating coils and electrical circuits, and with typical actual installations.

Members of the Founder Societies may obtain copies by sending $1.00 to the Engineering Societies Library, 29 West 39th Street, New York. Price to others is $1.25.

Letters to the Editor

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Speculations Concerning Employment Dynamics

To the Editor:

The article "Speculations Concerning Employment Dynamics", by Mr. Robert W. King, published in the April 1941 issue of ELECTRICAL ENGINEERING, is highly instructive, as it indicates that at last a justified doubt arises among responsible business leaders about many of our deep-rooted fallacious economic beliefs, and even that the realization dawns that these erroneous viewpoints may be the basic cause of our present world predicament. Mr. King's thoughts, as expressed in his address, should lead to some hard realistic thinking.

Among other thoughts he says:

"At long last, we are beginning to realize that any considerable and sustained degree of unemployment presents a serious threat to the foundation of liberal society. . . . In fact there are cogent reasons for believing, that the threat of war is itself inherent in insecurity of employment. . . .

"The vision of American industry running at ever higher speed appears to have at best a somewhat unsubstantiated foundation. . . . We might be well advised to harbor a suspicion that the mechanism which industrial society depends upon to maintain adequate—even expanding—employment, is in fact near a sort of overloading point. . . . The possibility of significant 'exports' to less developed areas will play a diminishing part in the economy of any geographical district. . . . Likewise such other forces as science and invention, may prove of uncertain value as agencies to bring about marked future expansion of employment. . . .

"With minor exceptions, American political philosophy has been guided by the vision of ever-expanding markets. . . . But surveying industrial history, one detects certain trends suggestive of saturation with its inevitable bearing upon the employment problem. . . .

"It is pertinent to inquire . . . whether a scheme of social security and social insurance can be woven deliberately into the technological fabric of the nation."

These statements are both encouraging and hopeful, despite their hesitancy of expression. They are encouraging because they indicate a general awakening and a desire to establish uncamouflaged facts about our social-economic situation. They are hopeful as an indication that at last humanity awakens from its lethargic sleep and is ready to search for and listen to a solution of saving our present civilization.

It should be welcome news therefore to learn that full mathematical proof can be provided to support Mr. King's statements as reiterated in the foregoing, and that thereby these statements can be elevated from a timid expression of opinion to a proved and unalterable fact. Such fact presentation is offered in the writer's latest engineering study entitled: "How to Save and Restore an Automatically Functioning Democracy in a World of Plenty, as Revealed by Engineering Research." This paper shows that superfluous labor is a natural and healthy result of the machine and power age with its abundant machine forces substituting for man power and that in consequence thereof such superfluous labor can and must be treated as a blessing instead of the present curse.

Calculating the machine power in terms of man power, I have shown that in Canada for each active worker (income earner), there is the equivalent of 500 man power in assisting machines. In other words, man has multiplied his own available man power at least 500 times, which means that for Canada alone the equivalent of 2 to $2^1/_2$ times the total world man power is constantly at work as machine power.

From this it follows that superfluous labor is an inevitable and healthy by-product of the new state of plenty. This fact being accepted, the next problem is to deal with the superfluous-man-power problem in a logical manner. Who is to do the nation's work, and how are goods and services to be allocated between active and superfluous man power?

The solution, suggested by my research, would be to let youth continue to do a nation's work by shifting superfluous labor into a leisure class of retired workers, restoring thereby individual self-reliance, rather than continuing the present scheme whereby the superfluous labor is treated as an outcast class of unemployed supported by charity. This would be accomplished by a nationally operated age-control, which would automatically lower the retirement age with growing superfluous labor. The retired worker would be retired at his normal net income up to which he worked himself while active.

The whole scheme would be effected by a compulsory national insurance scheme in which each income earner is included, with the income as the basis and the income tax his share of supporting his contemporary retired, but credited to him by the nation as an insurance premium on his own retirement policy.

The shrinking active-service period is feasible if the eternal partnership between youth and age is re-established, allowing youth to attend to the active work and arranging for age to enjoy the created leisure time but leaving the older people ready to stand by with wisdom acquired by experience during their active years.

Such shrinkage of the active-service period strives toward a definite lower limit, beyond which it cannot shrink because of the limitations set by the natural laws governing the rejuvenation process of a nation's personnel. This eternal law of rejuvenation demands that man must remain active long enough (approximately 20 years) to be able to acquire and pass on the accumulated professional knowledge of a nation from generation to generation, so as to avoid a gap or vacuum in the transmission of such knowledge and training.

As suggested above, the solution for this basic problem of unemployment is found to be a national retirement insurance. It will be based on income, the only measure of a man's worth to the collectivity. The income tax will be his premium on his own retirement policy, although in reality such tax will be used to support his contemporary retired in expectation that the same will be accorded to him by his next generation.

In the light of the aforementioned findings it will be readily realized that Mr. King's suggestion of industrial decentralization and closer contact with the farm community, is not basic enough to solve our problem, helpful though it doubtless might prove. Its fallacy as a radical cure lies in the fact that it tries to solve our problem economically, while its solution actually must be social.

The solution of a national retirement insurance as disclosed by the writer's engineering research on the other hand is basic and would doubtlessly lead rapidly to a stabler existence, the need of which Mr. King correctly stresses.

PAUL ACKERMAN (A'13)

(Consulting electrical engineer, Shawinigan Water and Power Company, Montreal, Quebec, Canada)

To the Editor:

The article, "Speculations Concerning Employment Dynamics" by Robert W. King (*EE, Apr '41, p. 151–6*) is particularly interesting to those who give thought to the position of fixed assets in our economic scheme. I can hardly come to any similar conclusion, regarding any "ceiling due to maintenance and depreciation," even if the numerical premises of his $10,000,000,000 estimate of annual maintenance and depreciation charges on the assets are admitted. "Durable family possessions" in accordance with his figures contribute $2,500,000,000 to this amount; the impact of larger "family holdings" would be felt mainly in this classification, while the other assets would be affected to a much lesser extent. Even a tenfold increase in the "holdings" would not result in expenditures out of line with what we are now demonstrating to be our real productive capacity.

Moreover, the assumed rates of depreciation reflect mainly the effect of technological obsolescence. In a semistabilized status of development (promoted by mass production), normal economic life expectancy increases substantially. The early automobile had a life of hardly more than five years, while today's improved model may well be kept in economical operation for over ten years. Such life expectancy may be further increased, when our systems of highways and traffic are more fully developed. Similar observations apply to housing, which is admittedly in a development status now; in Europe, normal life expectancy for urban dwellings, until recently, was about 80 to 100 years (bombings excepted).

A ceiling to personal possessions is, therefore, unlikely within the near future, particularly when the effect of standardization of materials and methods on utility and fixed charges is considered.

The engineer often misinterprets national income as the total of production and services. Actually, it is the residue, after deducting "disservices"—the cost of army, navy and police protection, illness, technical, economic and political waste and inefficiencies. It would be possible to raise substantially the net income, without increased production, by decreasing the disservices, and concentrating on production of socially desirable and desired goods and services.

There is a great deal of food for thought in this article. The engineer should be able to cut through the circular reasoning of our economists as to "purchasing power" and "productive capacity"—a fictitious problem, to concentrate on the more urgent question: Who is going to do the planning—the state or the individual? This appears to be the real subject of the present world struggle. Given a clear and sensible objective, the engineer can generally produce the desired result. But we must first devise means to ascertain the short- and medium-term objective in living standards of the thinking majority.

R. M. FISCHER (A'27)

(The American Appraisal Company, New York, N. Y.)

Total Security—A Challenge

To the Editor:

The address "Total Security—A Challenge" presented by Charles E. Wilson before the AIEE convention in January and printed in the March issue of ELECTRICAL ENGINEERING, has undoubtedly struck a sympathetic chord in the minds and hearts of many of those who heard or read it.

While others, like W. L. Batt, president of SKF, Charles R. Hook, president of The American Rolling Mill Company, and Robert W. King, assistant vice-president of the American Telephone and Telegraph Company, have spoken in similar vein, this is the first suggestion that I have seen for a definite program for the solution of the problem that will confront this nation—and the world—as soon as the defense and war activities begin to slacken. The conservative industrialists, engineers, and probably all financiers and bankers seem to be in agreement that we are heading for a cataclysm even worse than that following 1929, and that there is nothing that can be done to prevent it. It is encouraging, therefore, to see that there are leaders in industry who do have the scientific rather than the fatalistic point of view on this subject.

Now the main object of this letter is not so much to say how much I enjoyed the paper, as to inquire as to what more can be—or is being—done to further this cause. If it is not pushed along by those who believe in it, I am afraid we shall be wholly unprepared when the time comes. While the writer is in no position to know what is the best thing to do, he is wondering whether some concerted effort cannot be made through the appointment of committees of our national engineering, manufacturing, and business associations to study this subject and to co-operate with E. R. Stettinus' committee which is working along the same line.

This is undoubtedly the most important subject to be tackled next to our immediate defense effort, in order to avert the disaster that will befall us if we simply sit back and say that there is nothing we can do about it.

T. D. YENSEN (A'09, M'23)

(Manager, magnetic department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.)

Priorities in Men

To the Editor:

I want to express to you my appreciation for including the address by Doctor Harvey N. Davis on "Priorities in Men" in ELECTRICAL ENGINEERING for June 1941.

I hope that every engineer reading this will have re-emphasized to him the importance of the position of draft boards and that he will do everything he can to bring a true picture of each individual case to the members of the draft board concerned. The draft board setup is that which has been adopted in our country and one which we should progress. The members of the draft boards undoubtedly want to do the right thing, and if they are helped in each case by having a complete statement submitted for each person concerned, in the light of such complete statement they undoubtedly will be able to make comprehensive and satisfactory allocations. Doctor Davis has contributed much in bringing this matter to our attention and it is now up to each engineer to progress it as he may have opportunity, depending upon his location.

I was very happy, also, to see that President Sorensen in his message emphasizes this same matter to great advantage.

Also, W. S. Fielding's letter on "Engineers and the Draft" brings this matter to our attention in a very practical way.

I hope that these emphases will be actively progressed by all engineers.

EVERETT S. LEE (A'20, F'30)

(Vice-president, AIEE North Eastern District; engineer, general engineering laboratory, General Electric Company, Schenectady, N. Y.)

Wire and Cable Containers

To the Editor:

In the May issue of ELECTRICAL ENGINEERING, page 241, wire and cable manufacturers ask the return of containers.

In our plant in New York we have several hundred wood reels which can be purchased at a very reasonable price; principal sizes 36-inch, 32-inch, 28-inch.

These reels are the property of the British Ministry of Shipping and we have been asked to dispose of the reels at a fair price.

J. M. MACKENZIE (M'37)

(Anderson and MacKenzie, marine electrical engineers and contractors, 153 Mercer Street, New York, N. Y.)

St. Lawrence Seaway Opposed

To the Editor:

I have been unanimously directed by the membership of the Louisiana Engineering Society—an organization composed of over 500 professional chemical, civil, electrical and mechanical engineers—to inform you that once again our body has made a critical analysis of the engineering, economic, and National-Defense features of the proposed St. Lawrence Power and Seaway Treaty.

The Society once again has reached the conclusion that it is not in the best interests of our nation to engage at this time in such an undertaking as is proposed by the terms of the treaty, for the following reasons:

1. It is our opinion that the men, money, and materials necessary for the construction of the St. Lawrence waterway undertaking can best be utilized, at this time, in other more essential phases of Defense work.

2. It is a well-known fact that there is now available, and under construction, ample power for Defense needs, and furthermore, if such were not the case, the power developed from this proposed undertaking as well as the accompanying transportation facilities would be available too late to be of any help in the present crisis.

3. The Society is already on record as opposing any treaty that requires the consent or approval of

Canadian authorities, or of any authority other than the United States Congress, to permit further diversion of the waters from Lake Michigan which, with its entire watershed, lies wholly within the boundaries of the United States, since such diversion, or lack of it, has a vital effect on navigation in the upper region of the Mississippi Valley, and on the intrusion of salt water in the lower regions.

We would appreciate your advice as to whether the American Institute of Electrical Engineers can be of any assistance in bringing about the defeat of this measure, and what steps we should take to secure this assistance.

D. W. STEWART

(President, Louisiana Engineering Society)

Applications of Electric Power in Aircraft

To the Editor:

The valuable and comprehensive article by T. B. Holliday in the May issue of ELECTRICAL ENGINEERING has been read with great interest and the following comment is offered.

The suggestion is noted that storage batteries in aircraft may be replaced by additional generator capacity. With generators on a basis of six pounds per kilowatt this would appear justifiable; however, there are arguments to the contrary.

1. Some weight must be charged for ducts to produce forced cooling of generators. For large-sized generators some main engine weight rightly could be charged against generator output. With these additions to generator weight the battery for momentary loads will not appear at quite such a disadvantage.

2. There are peak loads in modern aircraft which normally last 15 to 30 seconds but which, in case of mechanical failure, may last much longer. An overloaded generator with sufficient excitation to maintain voltage at a relatively high value is more subject to injury by such an abnormal overload than is a battery.

3. The battery provides output independent of altitude, offers a brief emergency source of supply in case of main engine failure, and serves as a useful by-pass for radio-noise voltage.

In view of these points the advisability of complete elimination of batteries is questioned. For such purposes as supplying anchor lights for large boats no other supply appears suitable.

It is noted that a five-kilowatt accessory plant for engine starting is estimated to weigh 140 pounds. Such a plant would be in line with other estimates known to the writer, provided that the weight in question is that of the engine and generator alone. It has been found that necessary additions for mounting, enclosure, etc., add roughly 50 per cent to such net weight.

It is observed that normal continuous loads are required to have a voltage drop of less than 3 per cent. The power transmitted per pound of conductor, from a constant voltage source over a line of fixed length varies as $(1-K)K$, where K is the line drop expressed as a fraction. This product is maximum when

$$K=0.5$$

For values of K up to 0.1 or 0.15 the power transmitted per pound of conductor increases almost directly with the drop. Hence, for power loads, such as series motors, it would seem economical to permit a drop greater than 3 per cent. This will be particularly true if the main engine, taken as the primary source of electric power, is considered to have no weight and unlimited power output.

CARLOS B. MIRICK (A'08, M'22)

(Naval Research Laboratory, Washington, D. C.)

Power Distribution in Industrial Plants

To the Editor:

The group of papers and the informal conference dealing with various aspects of the problem of power distribution in industrial plants, were unusual features of the recent AIEE winter convention in Philadelphia. The writer was greatly interested in the technical material presented. The material was so technical, however, that only a graduate engineer would have much success in using the methods disclosed. The writer desires to call attention to some collateral problems involved and hopes that some interest may be aroused in the problem of developing means whereby these new ideas and methods may become practical and useful in the field.

In order to adapt this information to the needs of the field, we need a reasonably accurate picture of actual field conditions, which the writer believes is presented in the following paragraphs. Industrial-plant electricians and operators, whose technical training is that of electrician apprentice, supplemented in some cases by vocational school training and in a few cases by either university-extension or correspondence-school courses, comprise the vast majority of those doing plant "engineering" work. A few graduate mechanical engineers and still fewer graduate electrical engineers are to be found in this group. The writer has had repeated conferences with both types and also with utility power sales representatives. The pictures presented by these groups, so different in background, training, experience, and outlook, are astounding in their sameness. It is this very unanimity of thought that forces the writer to believe the resultant picture to be essentially correct.

What, then, is the picture? Basically, it is that small and medium-sized plants (say up to 4,000 or 5,000 kw maximum demand) show little real engineering in their original layout and practically none in extension or rearrangement. Larger plants (up to 10,000 or 15,000 kw maximum demand) will show considerable real planning in their original layouts, but for growth or rearrangement, "by guess and by gosh" methods appear to be the rule. Surprising as it may be, this generalization appears to hold, even in those instances where a very large corporation has a number of plants and a fair-sized headquarters staff charged with "plant engineering". Of course, a number of notable exceptions are to be found, but it appears safe to say that more than 90 per cent of our industrial plants have not been engineered, but like Topsy, have just "growed".

Why does such a situation exist? The answer seems to be that management thinks of plant electricians, plant engineers, and plant electrical systems as possibly necessary but nevertheless irritating nuisances. Management, by nature, evaluates everything on the dollar sign. They see the expenses, both operating and capital, caused by this group. They fail to see the economic gains produced. The writer suspects that this situation is largely the fault of the plant people themselves. In a word, they have not sold themselves nor their work.

Some constructive comments would appear to be in order. First, management must be sold on the economic value of more real engineering in this field. The committee on industrial applications could aid by sponsoring articles, emphasizing the economic aspects, in such magazines as *Factory Management and Maintenance* and similar publications read by managers and executives. Second, technical knowledge and methods of applying this technical knowledge in an economic manner must be got into the hands of these plant engineers, not only the 5 or 10 per cent who are graduate engineers but the 90 or 95 per cent who have come up from the rank and file. How to reach this group is a real challenge. A few are Associates or Members of the Institute. The vast majority are not.

A few suggestions made at the Philadelphia conference will be stated in condensed form. First, a considerable mass of technical data and calculating procedures exist. Could not this material be correlated, condensed, reduced to chart and table form? Could not the simpler problems of economic evaluation be similarly treated? Such material could then be published as a simple monograph or handbook. Second, industrial power groups might be formed within the Sections of the Institute. If this idea is not practical in certain areas, similar groups might be formed under the immediate auspices of a local electrical league, or conferences might be organized by a local utility company or a community executive club. In any case, there appear to be two jobs in any attempt of this nature. One is to develop a real program and the other is to give it publicity so that the man who could most benefit would know that such a program was available. Third, good practical articles might be written and published, not so much in ELECTRICAL ENGINEERING, as in the semi-technical press, trade bulletins, or even house organs.

Many of the activities implied by the suggestions outlined appear to be outside of the range of the usual Institute program. However, would not such activities be a most useful and practical way of accomplishing a basic purpose of the Institute, namely that of increasing the practical knowledge and practical use of electricity?

PAUL S. CREAGER (A'19)

(Associate professor of electrical engineering, Rutgers University, New Brunswick, N. J.)

Transmission-Line Vector Models

To the Editor:

In a previous contribution (*EE, Feb. '41, p. 95*) it was shown that the hyperbolic sine and cosine of a complex variable could be interpreted in terms of the difference or sum, respectively, of two exponential spirals, corresponding to the transmitted and reflected components of the current

Figure 1

and voltage waves on an open-circuited transmission line. One objection to diagrams of vector loci, such as the illustrations in the previous contribution, is the difficulty experienced in correlating corresponding points on the different curves. Such diagrams are essentially two-dimensional representations of three-dimensional curves, with the axis of the independent variable omitted.

The representation of vector loci, such as the distribution of voltage and current on transmission lines, best may be obtained by the use of three-dimensional models. Many schools have constructed such transmission-line models, with the third dimension used to represent the distance along the line. These models generally have been so tedious to construct that few schools have been able to assemble a sufficiently complete collection of them. At Southern Methodist University it has been found that satisfactory models may be assembled in surprisingly short time with the aid of a small spot welder, such as is used for the construction of vacuum tubes. The models have been constructed by students in the transmission course as laboratory projects. Most students have little difficulty in learning to use the welder and seem to benefit greatly from designing and constructing these models.

Figure 1 shows an electrical-engineering student assembling a model with the welding jig that has been developed for this work. This jig has distance, magnitude, and angle scales, and figure 2 shows the essential features of its construction. Figure 3 shows three typical models that have been constructed with this jig. The center model is a simple exponential spiral,

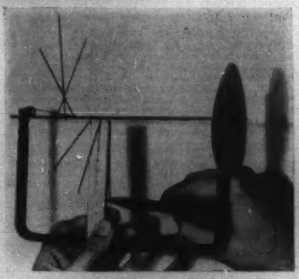


Figure 2

illustrating the propagation of voltage or current along a line which is terminated in its characteristic impedance, and which consequently produces no reflections. The left-hand model illustrates the combination of two exponential spirals to form the hyperbolic sine of the complex variable. Consequently, it may be used to illustrate the combination of the transmitted and reflected current waves on an open-circuited line, or of the corresponding voltage waves on a short-circuited line. The right-hand model is for the hyperbolic cosine and has a similar transmission-line interpretation.

The exponential spiral was constructed in one and one-half hours, while the hyperbolic models each required about four hours. The axes of these models are nine-inch lengths of one eight-inch diameter drill rod and the vectors and loci wires are ordinary black iron "stove-pipe" wire. The cost of materials was less than six cents each. These small models are satisfactory for use with small classes, but the same method can be used for the construction of much larger models.

S. G. Lutz (A'38)

(Naval Research Laboratory, Washington, D. C.)

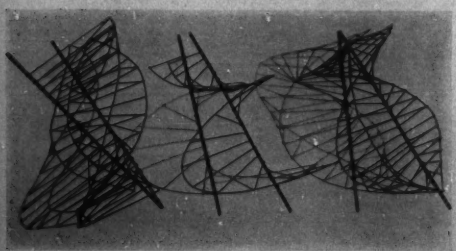


Figure 3

Books Received •

Engineering Employment and Earnings. The report on "Employment and Earnings in the Engineering Profession 1929 to 1934," prepared by the Bureau of Labor Statistics at the request of American Engineering Council has been issued as a bulletin of the United States Department of Labor. Articles embodying sections of the report, which was prepared by Andrew Fraser, Jr., were published during 1936 and 1937 in the *Monthly Labor Review*, and reprinted in part in Electrical Engineering for the same years. In addition to the material included in these preliminary articles, the final report summarizes conclusions from the various analyses. Special emphasis is laid upon the limitations of its results for the purpose of forecasting employment and salary trends in engineering. This was the first study of its kind to be made by the Bureau; with the establishment of the Occupational Outlook Service, other similar surveys are to be made in the future. Copies of the bulletin may be obtained from the Superintendent of Documents, Washington, D. C., at 25 cents each.

"Power System Interconnection." Written to acquaint the practicing engineer as well as the advanced student with the analytical and graphical methods developed for calculating the performance of interconnected power systems, this book by H. Rissik is purposely limited in scope to a consideration of the basic transmission problems underlying the technique of modern system interconnection. Much of the material is based upon articles by the author which have appeared in the technical press. References follow each chapter and a chronological bibliography is included. Published by Sir Isaac Pitman and Sons, Ltd., London, 1940; price $7.50.

"Mathematical Tables." A series of "Mathematical Tables of Elementary and Some Higher Mathematical Functions Including Trigonometric Functions of Decimals of Degrees and Logarithms" has been prepared by H. B. Dwight, professor of electrical machinery, Massachusetts Institute of Technology. Copies of the book, which contains 231 pages including an index, may be obtained from the publishers, McGraw-Hill Book Company, New York, N. Y., at $2.50 per copy.

"Industrial Research Laboratories of the United States." The seventh edition of this directory contains information concerning 2,264 industrial concerns which maintain one or more research laboratories. This is 469 more concerns than were listed

in the sixth edition issued in December 1938. Indexes cover the geographical distribution of laboratories, the personnel, and the subject of the research activities. The personnel index includes the names of about 6,900 research workers. 372 pages. National Research Council, Washington, December 1940; price, $3.50.

The following new books are among those recently received at the engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

ATM (Archiv für technisches Messen), Lfg. 106, 114, 115, April 1940, December 1940, January 1941. R. Oldenbourg, Berlin. T37-48; T130-139, F6, 7; T1-15, F1. Illustrated, 12 by 8½ inches, paper. 1.50 rm. each. Three numbers of a monthly publication containing classified articles upon various types of apparatus and methods for technical measurements. Some of the numbers also contain descriptions of specific instruments manufactured by German companies.

AMERICAN SOCIETY FOR TESTING MATERIALS. PROCEEDINGS OF THE 43D ANNUAL MEETING. Held at Atlantic City, N. J., June 24-28, 1940, volume 40, 1940. American Society for Testing Materials, Philadelphia, Pa. 1396 pages, illustrated, 9 by 6 inches, cloth, $9.00. The major part of this annual volume is devoted to the technical papers, including discussions, presented to the society during the year indicated. The book also contains the summary of the proceedings of the annual meeting and the reports of the various technical committees.

AMERICAN YEAR BOOK. A Record of Events and Progress, Year 1940. Edited by W. M. Schuyler and A. H. Hazen. Thomas Nelson & Sons, New York, 1941. 1079 pages, tables, 8 by 5 inches, cloth, $7.50. This annual presents a survey of events during the year 1940 in 27 major fields of activity. Business, finance, and science are represented, including surveys of the mineral industries, manufactures, transportation, mathematics, chemistry, physics, engineering, and construction. The material is contributed by recognized authorities. Lists of related periodicals, societies, and research institutions accompany each section, and there is a comprehensive index.

THE ANODIC OXIDATION OF ALUMINUM AND ITS ALLOYS. By A. Jenny, translated by W. Lewis. Chemical Publishing Company, New York, 1940. 231 pages, illustrated, 9 by 6 inches, cloth, $6.50. Deals with electrolytic and chemical production of protective films on aluminum and its alloys, and with their uses in practice. An introduction presents the relevant electrochemical theory. The original text, as translated from the German, has been supplemented with additional information.

ARSENAL OF DEMOCRACY. How Industry Builds Our Defense. By B. Finney. McGraw-Hill Book Company, Whittlesey House, New York, 1941. 284 pages, illustrated, 8½ by 5½ inches, cloth, $2.50. This author of "American Aristocrat" examines the national-defense program from the production point of view. Reasons for the delay in the establishment of mass production are given; the plan by which industries are outlined; and the effect of the program on industry, labor, and living conditions is discussed.

DESIGN FOR INDUSTRIAL CO-ORDINATION. By R. W. Porter. Harper and Brothers, New York and London, 1941. 249 pages, diagrams, etc., 9½ by 6 inches, cloth, $3.00. A management consultant shows the structure of business organization and the elements of co-ordination which make it function efficiently as a technical design within which management must operate for best results. Problems of industrial management are classified, and 21 elements of performance given upon which the author bases the effectiveness of the general pattern. Ways to measure results are indicated.

DYKE'S AUTOMOBILE AND GASOLINE ENGINE ENCYCLOPEDIA. By A. L. Dyke. 19th edition. Goodheart-Willcox Company, Inc., Chicago, 1941. 1483 pages, illustrated, 10 by 7 inches, cloth, $6.00. Manual on automobiles and internal-combustion engines for students, repairmen, and owners. Topics covered include the principles, description, and operation of all mechanical, propulsive, and electrical parts of an automobile, maintenance, testing and repair, specifications and definitions. New material on aircraft engines and their accessories, automotive Diesels, fluid drive, automatic transmissions, and other recent developments. General and supplementary index.

ELECTROMAGNETIC DEVICES. By H. C. Roters. John Wiley and Sons, New York, 1941. 561 pages, illustrated, 9 by 6 inches, cloth, $6.00. The fundamentals, characteristics, and design of electromagnets are presented for graduate students and practical engineers. Background theory and methods applicable to all types of magnetic circuits and nonrotary electromagnetic devices, are first developed, then applied to a variety of problems. Special attention is paid to magnetic leakage and nonlinear relationships.

FARES, PLEASE! From Horse-Cars to Streamliners. By J. A. Miller. D. Appleton-Century Company, New York, 1941. 204 pages, illustrated, woodcuts, 10 by 6 inches, cloth, $3.50. A picture of city transit from the time of the first horse-drawn omnibus to the present day. Describes the various means of transport, including their development, their problems, and the personalities involved. Unusual types of transit and the methods used to meet transportation problems in crowded cities are also discussed.

HIGH-SPEED COMPRESSION-IGNITION ENGINE. By C. B. Dickson. Blackie and Son, London and Glasgow; Interscience Publishers, New York, 1940. 331 pages, illustrated, 9 by 6 inches, cloth, $4.50. The principles governing the operation of high-speed compression-ignition engines are dealt with in detail, including discussions of associated problems. Chapters on the fundamental chemical and thermodynamical theory and on fuel injection.

THE HIGH-SPEED INTERNAL-COMBUSTION ENGINE. By H. R. Ricardo, revised by H. S. Glyde. Interscience Publishers, New York; Blackie and Son, Ltd., London and Glasgow, 1941. 434 pages, illustrated, 10 by 6½ inches, cloth, $7.50. This work upon the characteristics and design of high-speed internal-combustion engines has been revised again to conform with current practice. Some parts, the chapter on high-speed Diesels in particular, have been completely rewritten.

HIGHWAY SAFETY AND AUTOMOBILE STYLING. By A. W. Stevens. Christopher Publishing House, Boston, Mass., 1941. 155 pages, diagrams, 8 by 5 inches, cloth, $1.75. Describes the general conditions of highway travel, points out contributory factors of importance in causing accidents, and suggests remedies. The emphasis is on the redesign of automobiles to put the driver at the very front of the car, in order to increase visibility. The conclusions are the result of a six-year investigation of the problem.

HISTORY OF MAGIC AND EXPERIMENTAL SCIENCE. Volumes 7 and 8. The Sixteenth Century. By L. Thorndike. Columbia University Press, New York, 1941. Volume 5, 695 pages; volume 6, 766 pages, 9 by 5½ inches, cloth, $10.00 per set of two volumes. These two volumes, covering approximately the period from 1500 to 1630, complete a monumental study of magic and experimental science during the first 16 centuries of the Christian era. It integrates the two fields, outlines the interrelations of science and society, and presents a considerable amount of new material. An index to these two volumes, occupying some 150 pages, is included in volume 6.

MATRIX AND TENSOR ALGEBRA FOR ENGINEERS AND CHEMISTS. By C. E. Rose. Chemical Publishing Company, New York, 1940. 143 pages, tables, 9½ by 6½ inches, cloth, $4.00. Attempts to present the elements of determinants, vectors, matrices, and tensors in such a way as to enable the physicist, chemist, or engineer to understand and apply them to technical problems. A kn owledge of ordinary alcebra and the differential calculus is assumed. Illustrative problems.

OXYGEN-BOOSTING OF DIESEL ENGINES FOR TAKE-OFF. By P. H. Schweitzer and E. R. Klinge. Pennsylvania State College, Engineering Experiment Station Bulletin No. 54. State College, Pa., 1941. 20 pages, illustrated, 9 by 6 inches, paper, $0.50. Describes an investigation to determine the effect of feeding oxygen into the intake air of a Diesel engine, with special reference to the use of this procedure in the case of airplane Diesels during take-off time.

PUBLIC UTILITY ECONOMICS. By C. W. Thompson and W. R. Smith. McGraw-Hill Book Company, New York and London, 1941. 727 pages, illustrated, 9½ by 6 inches, cloth, $4.50. Designed as a textbook for advanced students in economics and commerce, this book relates the field of public utilities to the broader area of economics. Shows the place which public utilities occupy within our economic structure, and discusses such special problems of price control, service supervision, security regulation.

REPORTS ON PROGRESS IN PHYSICS. Volume 6. Edited by J. H. Awbery. The Physical Society, c/o Imperial Institute, Exhibition Road, London, S.W.7, 1940. 434 pages, illustrated, 10 by 7 inches, cloth, 22s 6d. Follows the trend of previous volumes of the series in devoting an increasing proportion of space to articles on the recent advances in such specific topics as the separation of isotopes, the cyclotron, the properties of liquid helium, superconductivity, impedance networks, etc. Includes also general reviews of a few of the broader fields, such as sound and heat. Each article has a bibliography.

TABLES OF SINE, COSINE, AND EXPONENTIAL INTEGRALS, Volume 1. Prepared by the Federal Works Agency, Work Projects Administration for the City of New York, conducted under the sponsorship of the National Bureau of Standards, Washington, D. C., 1940. 444 pages, charts, tables, 11 by 8 inches, cloth, $3.00. The functions indicated are tabulated in this volume over the range from 0 to 2 at intervals of 0.0001. There are also supplementary tables, a bibliography of papers in which these functions have been applied to various technical problems, and lists of reference texts and of the best tables of the functions.

TECHNIK GESCHICHTE. (Beiträge zur Geschichte der Technik und Industrie, Band 28, 1939). VDI-Verlag, Berlin, NW 7. 188 pages, illustrated, 11½ by 8 inches, cloth, 8 rm. The latest issue of this annual presents developments during the present century in various industrial fields. Subjects include the advances in methods of testing materials, in iron smelting, bearings, electric furnaces, textile machinery, hydraulic engineering, the development of belt transmissions, the history of alternating currents and of electric meters, galvanic electricity, and mercury mining.

TECHNOLOGY AND SOCIETY. The Influence of Machines in the United States. By S. M. and L. Rosen, with an introductory chapter by W. F. Ogburn. Macmillan Company, New York, 1941. 474 pages, illustrated, 9 by 5½ inches, cloth, $3.00. The interrelations between technology and the social scheme as they affect present-day life are presented in a simple, balanced manner. The four main sections deal respectively with the technologic base and economic, social, and political effects. Intended particularly for undergraduate students in the social sciences and engineering. Suggestions for further reading are included.

TEMPERATURE MEASUREMENT. By R. L. Weber. Edwards Brothers, Inc., Ann Arbor Michigan, 1941. 171 pages, illustrated, 11 by 8½ inches, paper, $2.50. Presents the substance of a course offered for juniors by the physics department of the Pennsylvania State College. Part I covers the theoretical basis for all the important methods of temperature measurement. Part II contains a comprehensive group of tested illustrative laboratory experiments. Bibliographical references and review exercises are included.

THE WORLD AND THE ATOM. By C. Møller and B. Rasmussen, with foreword by N. Bohr. D. Van Nostrand Company, New York, 1940. 199 pages, illustrated, 9 by 5½ inches, cloth, $2.75. The development of modern atomic physics from the end of the last century to 1939 is briefly described for the layman. General physical concepts have been included wherever necessary. Translated and revised from the original Danish.

PRINCIPLES OF INLAND TRANSPORTATION. By S. Daggett. Third edition. Harper and Brothers, New York, 1941. 906 pages, illustrated, 9½ by 6 inches, cloth, $4.00. Intended as a college text, covers road, rail, water, air, and pipe-line transport, chiefly with respect to the United States. Early chapters present a brief historical survey and a consideration of transportation geography. Subsequent sections discuss rates, competition, labor and finance, relations of carriers with each other, and relations between carriers and users. The problems and practice of regulation have been given full consideration. New edition has been revised for current use.

THE WHEELER PROJECT. Technical Report No. 2 of the United States Tennessee Valley Authority, Knoxville, Tenn. Government Printing Office, Washington, D. C., 1940. 362 pages, illustrated, 9 by 6 inches, cloth, $1.00. A brief history of the Tennessee River development and the part played by the Wheeler project precedes a description of the project investigations, including social and economic studies, the engineering design and construction work, the operations, and reservoir adjustment. Complete summary of construction costs. Various special reports and test results are appended. Bibliographies.

HEATING, VENTILATING, AIR CONDITIONING GUIDE, Volume 19, 1941. American Society for Heating and Ventilating Engineers, New York. 1120 pages, illustrated, 9 by 6 inches, cloth, $5.00. The annual revision of this comprehensive manual provides designers and installers of apparatus for heating, ventilating, and air conditioning with up-to-date information. The theory and practical application presented cover both domestic and industrial practice. In addition to necessary revision the chapters have been rearranged. The Guide also contains a catalog data section listing apparatus and materials, a glossary of terms, and the membership list of the Society.

CROSBY-FISKE-FORSTER HANDBOOK OF FIRE PROTECTION. Edited by R. S. Moulton. Ninth edition. National Fire Protection Association, Boston, Mass., 1941. 1308 pages, illustrated, 7 by 4½ inches, leather, $4.50. Contains essential information on all phases of fire prevention and fire protection. New developments during the past five years in hazards, protective equipment, and methods have been included in this revision.

Transactions Section

Preprint of Corresponding Pages From the Current Annual Transactions Volume

Any discussion of these papers will appear in the December 1941 "Supplement to Electrical Engineering—Transactions Section"

Large Electric-Arc Furnaces—Performance and Power Supply

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ELECTRIC arc furnaces are desirable loads for power systems, and are becoming more and more used for producing high-grade alloy steels, as well as for other types of steel. The authors believe that the data in this article will be of value and assistance to others in the solution of similar problems.

It is necessary in connecting large electric arc furnaces onto power systems that it be done in such a manner that neither the voltage changes, caused by the violent and rapid load swings of these furnaces, will interfere with other load of the furnace customer nor be permitted to reflect back into the system in such a manner as to interfere with service to adjacent customers. Also precautions must be taken so that such widely fluctuating loads will neither interfere with the operations of any of the equipment on the power system nor interfere with any interconnection with adjacent power companies. Further, precautions must be taken so that voltage regulation caused by large short-time loads will not be too great.

Paper 41-40, recommended by the AIEE committee on electrochemistry and electrometallurgy, and presented at the AIEE winter convention, Philadelphia, Pa., January 27-31, 1941. Manuscript submitted October 8, 1940; made available for preprinting December 10, 1940.

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1. For all numbered references, see list at end of paper.

Summary

In March 1940, a 25-ton Heroult 3-phase electric arc furnace using a 10,000-kva furnace transformer was connected to the Duquesne Light Company system, and in August 1940, a second furnace duplicating the first was installed at the same location. These installations were made by the Pittsburgh Crucible Steel Company at their Midland, Pa., plant near Pittsburgh.

It was believed that the load swings on the first furnace with the accompanying voltage changes would exceed the standards which the Duquesne Light Company had established for this type of load, viz.

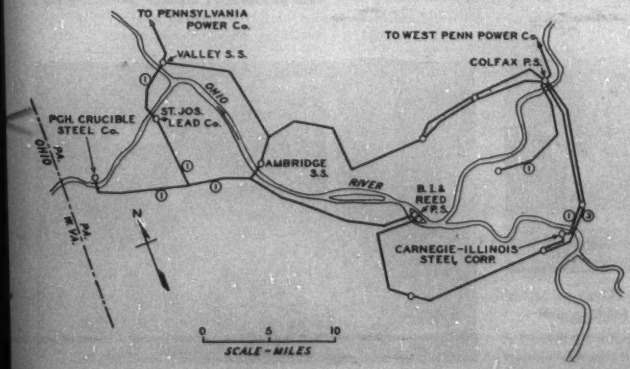


Figure 1. Diagram of power system showing 66-kv lines and power stations

Each line on diagram represents two 50,000-kva lines unless noted. Duquesne Light generating capacity is 504,000 kw with a 60,000-kw unit scheduled for service in July 1941

All lines are double-circuit unless noted by (1) or (3)

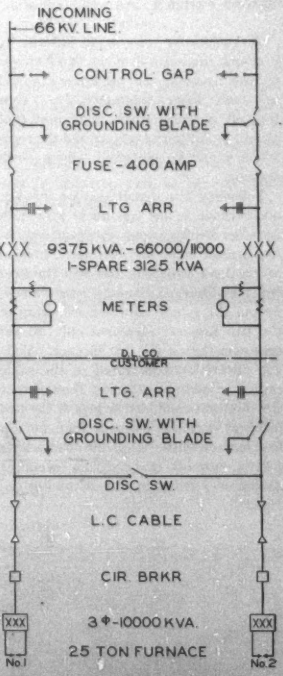


Figure 2. Diagram of power-supply substation and furnace substation

The 400-ampere 66-kv fuses provide protection for high-voltage and low-voltage faults

1.5 volts (115-volt base) for the 66-kv system with fluctuations from 3 per hour up to 15 per minute. Precautions were taken in the design of the furnace transformer to include separate reactance to reduce the load swings. Subsequently, it was found that this additional reactance was not eneded and it was removed, thereby improving the operation of the furnace.

The load swings and accompaning voltage changes, after disconnecting the reactance, due to the operation of the first furnace, slightly exceeded the Duquesne Light Company standards. However, no complaints have been received from adjacent customers nor have any difficulties arisen from excessive operation of 4-kv distribution regulators, operation of the power stations, or interconnections.

Second Furnace

Arrangements were made initially to interlock the controls of the two furnaces in such a manner that the furnaces would not melt down simultaneously. Thus the voltage flicker would not exceed that caused by the initial furnace and the regulation would be increased only a small amount.

Following the installation of the second furnace, a test was made with both furnaces melting down simultaneously at the highest secondary voltage. Instead of the load swings of the two furnaces being additive, the swings were diversified to the extent that the net swing of the two furnaces increased only 20 per cent over that of the first furnace. Voltage disturbances increased in the same ratio. In addition, the test showed that the resultant combined swings of the two furnaces were less frequent than for the first furnace alone. Thus the interlocking scheme may not be necessary except as a means of reducing the 15-minute demand.

Method of Approach

This article contains a rather complete treatise of our investigations and presents the industry with these data which the authors hope will be of some use to others in the solution of their furnace problems.

Some data have been published on electric furnace performances and the power system supply (see bibliography), but for the first large installation on any power system the authors strongly recommend getting all data that they can possibly lay their hands on, and making a thorough analysis of them.

Obviously, the correct engineering approach is to determine in advance what the kilovolt-ampere swing and resultant voltage flicker will be, and to provide a suitable system connection with corrective equipment if necessary, to keep the voltage changes within tolerable limits. However, this is not always so easy, for in some cases it is difficult to find out just what the electric performance of the furnace will be.

In addition to the determination of instantaneous load changes, the maximum loads which exist for several seconds at a very poor power factor, and which occur several times during a heat, should be determined. These large loads may result in undesirable voltage regulation on the customer's supply bus or at adjacent customers.

There are many factors involved, and many calculations to be made, not only for normal system conditions but also for the abnormal system condition of reduced capacity, lines out of service, generators off the line, etc. These abnormal conditions may result in voltage disturbances beyond standard voltage limits. However, it will probably not be economical to reduce the voltage changes to standard limitations with lines and equipment out of service because of their infrequent occurrence.

Calculations

Having decided upon the maximum instantaneous furnace load swings, the voltage flicker at the customer's supply bus should be determined from the known or estimated system impedance at that point. The voltage flicker, then, at the nearest customer or substation should also be determined.

The per cent system impedance to the Pittsburgh Crucible Steel Company 66-kv bus in 68-kv terms and on a 10,000-kva base in $R+jX$ terms is:

$(1.1+j4.0)$ per cent

The reactance of each of the 66/11-kv 9,375-kva transformer banks supplying the furnace transformers is 6.0 per cent on a 10,000-kva base. The system impedance is based upon all generating units and all 66-kv lines in service and the West Penn Power tie closed at Colfax.

As the furnace load swings are generally at a very poor power factor, the use of system reactance at the customer's bus will give fairly close results. This system reactance is that ordinarily determined by a short-circuit study. However, the true power does change considerably and if this change and the change in the reactive power are known, then the calculations of the voltage change based upon system impedance rather than reactance will give more accurate results.

The calculations for voltage regulation may be made in substantially the same manner, as described above for voltage flicker.

Application of Corrective Equipment

If the voltage changes calculated as described under the preceding heading

Figure 4. Photograph of charging side of a 25-ton Heroult three-phase electric-arc furnace at Pittsburgh Crucible Steel Company, Midland plant

Figure 3. Photograph of power-supply substation—66/11 kv, 18,750 kva—at Pittsburgh Crucible Steel Company, Midland plant

Incoming 66-kv line at left and 11-kv circuits to furnace transformers at right. Lightning arresters mounted at high-voltage transformer bushings

exceed the allowable values, then corrective equipment should be applied. Discussion here will be limited to correction obtained by synchronous condensers. This as well as other methods of correction have been described by earlier papers, see item 1 in bibliography.

As far as very frequent instantaneous furnace load changes are concerned, the condenser will draw additional leading reactive current to offset some part of the additional reactive furnace load. For a general analysis, it can be considered that the system and the condenser will share the increased furnace reactive load in proportion to the inverse of their respective reactances. Thus the reduction in voltage flicker may be estimated as well as the amount of corrective capacity to obtain the desired reduction.

The condenser can be made to draw more leading reactive current by increasing the system reactance. This may be done by installing a buffer reactor in the furnace supply circuit ahead of the condenser. Actually, this buffer reactor produces increased voltage drop at the terminals of the condenser thus causing it to draw more leading reactive current. The condenser will draw increased leading reactive current in proportion to its subtransient reactance. Thus the speed of condenser field has very little to do with the correction of very rapid furnace reactive changes. Speeding up the field will, however, materially improve regulation for large load changes which last for several seconds.

Duquesne Light Company System and 66-Kv Supply to Furnace

Figure 1 shows the Duquesne Light Company system, including generating stations and the 66-kv transmission ring. The two major sources of interconnections with adjacent utilities are shown, one at Colfax with the West Penn Power Company and the other at Valley substation with the Pennsylvania Power Company. The latter is normally open, but in emergency can be closed and operated in parallel with the other systems, the 40,000-kva regulating transformer between the two systems being able to control both true power flow and reactive flow, the latter providing voltage regulation at this point, see items 6 and 7 in bibliography.

A single 66-kv circuit, ACSR 336,400 circular mils (4/0 equivalent) tapped to the single circuit between Ambridge substation and St. Joseph lead substation, was extended nine miles on wood poles with two ground wires to the Pittsburgh Crucible Steel Company at Midland, Pa. There is an extra degree of insulation and ground protection built into this extension which will make it practically immune from insulation troubles.

Supply Substation

Figure 2 shows the supply substation schematically for the 2 25-ton Heroult furnaces. Figure 3 shows the photograph of the substation with 2 9,375-kva transformer banks and one single-phase spare unit. Normally, each bank supplies one furnace independently and the 11-kv bus tie disconnecting switch is closed only in case one bank is out of service. At this time the furnace must be operated at a reduced secondary voltage to keep the load on the one 9,375-kva bank within its limit.

Figure 5. Photograph showing the pouring of 40 tons of high-grade alloy steel at Pittsburgh Crucible Steel Company, Midland plant

Note the entire furnace tilting to facilitate pouring

Tests on First Furnace

Tests were run during a complete heat on the first 25-ton Heroult furnace shown on figure 4 and figure 5.

Table I. Pittsburgh Crucible Steel Company, Midland, Pa.

Test on 4/10/40

Sec. Voltage	Point	No. on Meter Charts	Kw	Reactive Kva	Kva Calculated	Three-Phase Power Factor Calculated*	11-Kv Voltage	Amperes at 11 Kv A	Amperes at 11 Kv B	Amperes at 11 Kv C	Kva Calculated**	Single-Phase Power Factor† (Per Cent) Point	Avg.	Max.	Min.
220	1 High		6,550	6,660	9,300	70.5	10,500	655	750	624	12,300	50			
	2 Low		2,280	300	2,300	99.2									
	Inst. change				7,000										
	3 High		7,200	8,700	11,300	64.0	10,000	804	760	792	13,400	50			
	4 Low		2,880	1,680	3,300	87.3									
	Inst. change				8,000								50	98	50
	5 High		7,250	8,640	11,300	64.2	10,350	866	724	892	14,800	54	Average for 220 volts		
	6 Low		2,400	1,200	2,700	89.0	11,000	192	240	240					
	Inst. change				8,600			674	484	652					
	7 High		6,900	9,840	11,500	52.1	10,000	703	792	888	15,000	60			
	8 Low		3,240	1,320	3,500	92.5	10,850								
	Inst. change				8,000										
240	9 High		8,700	11,520	14,430	60.3	9,400	883	1,065	1,100	16,500	50	85	95	50
	10 High		8,650	11,320	14,400	60.0	10,300	1,060	1,026	1,043	18,600	50			
	Low		5,150	4,800	9,400	86.8		556	605	580					
	Inst. change				5,000		9,770	504	421	463					
220	11 High		4,800	11,500	12,460	38.5	9,250	916	960	760	14,100	50	85	97	50

All measurements are "input to furnace transformers" and adjacent to furnace transformer.

*Calculated on basis of three-phase kilowatts and three-phase reactive kilovolt-amperes input.

**Calculated on basis of average amperes per phase and *AB* voltage.

†Power factor from charts using *A* amperes and *AB* and *CB* voltage.

General: The average power factor for loads during the refining period varies between 85 and 95 per cent. Inst. change—instantaneous change.

Graphic Meter Records

Graphic records were obtained of customer's 11-kv voltage, furnace reactive kilovolt-amperes, kilowatts, amperes in each phase and single-phase power factor, and 66-kv voltages at the nearest attended substations. Sections of these charts during different periods of the heat are shown in figures 6, 8, 10, 12, and 13. These charts were run at approximately six inches per minute speed.

The seven meters at the furnace were driven by a common shaft and a switch was installed to short circuit the current transformers and open the potential leads simultaneously. This switch was operated at 15-minute intervals to aid in synchronizing the charts for analysis purposes.

In order to run the charts at high speed, most of the damping effect is eliminated. This undoubtedly allowed the meters to overswing.

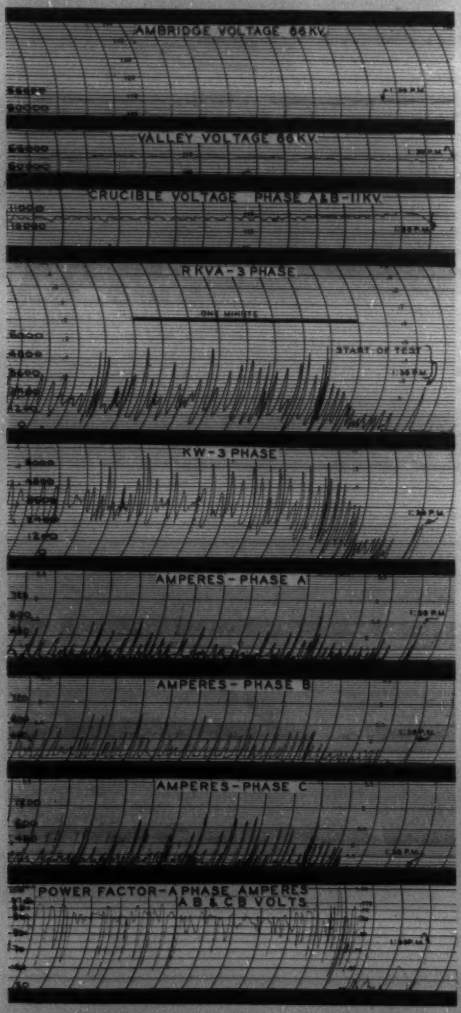
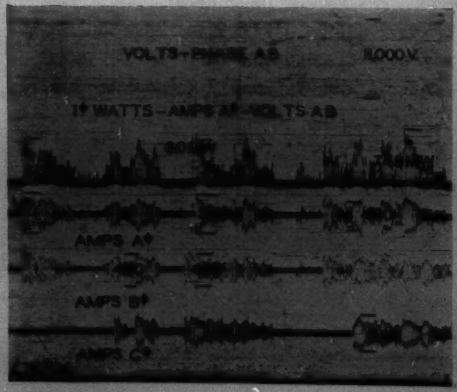


Figure 6. Graphic charts at start of heat at 1:38 p.m.

Furnace swings occur approximately once a second

Figure 7 (below). Oscillograph film at start of heat

A single-phase arc struck and restruck ten times in the space of 15 seconds before all three phases struck. After this initial period, all three phases struck and restruck ten times with currents in all three phases fairly well balanced before the arcs became generally stable. A portion of this performance is shown on this figure



Oscillograph Records

An oscillograph record was taken at several points during the heat. Portions of these records are shown in figures 7, 9, 11, and 14. The record of the single-phase wattmeter is intended to show the rapid changes in furnace consumption and not the true single-phase load, in so far as the single-phase wattmeter is 30 degrees out of phase with three-phase balanced loads.

It is almost impossible to obtain oscillograph records of the maximum loads or changes in loads because of their short duration.

Results

Table I shows various values obtained from the graphic charts of kw, reactive kilovolt-amperes, amperes, volts, and power factor. These values are instantaneous ones taken during maximum furnace load swings or furnace loads. Several of the numbered points are shown on the exhibits.

The maximum instantaneous furnace load swing, lasting a fraction of a second, amounted to 8,600 kva, 3 phase with a calculated power factor of 54.5 per cent (change in load). An analysis of the load swings indicated that the maximum occurred only once and only ten exceeded 7,000 kva during the heat.

The maximum instantaneous load of seconds duration, was found to be 14,400 kva or 144 per cent of the furnace transformer rating.

Based upon maximum load swings (8,600 kva) the voltage flicker at the nearest 66-kv customer (St. Joseph Lead Company) amounts to 2.3 volts, at Valley substation, 2.1 volts, and at Ambridge substation, 1.8 volts. See figure

1 for locations. However, due to the fact that the majority of the load swings were considerably less than the maximum, no complaints have been received from adjacent customers and no difficulties have arisen from excessive operation of 4-kv distribution regulators or in the operation of the power station or interconnections.

Thus perhaps corrective equipment should not be installed to correct for the maximum swing but for something less than the maximum, assuming that a few voltage changes in excess of the standard could be allowed.

The location of the furnaces at the end of a long line and with considerable impedance to the supply bus, probably accounts for the fact that the load swings and maximum loads are less than might be expected from a furnace of the size installed.

Due to the fact that no other customers are located near the furnace installation the voltage flicker and regulation at the customer's 66-kv bus are allowed to exceed values that would normally be allowed and the voltage changes at the nearest customer are materially less due to the relatively high impedance between it and the furnace 66-kv bus.

Table II shows the 15-minute kilowatt demand during each 15-minute period of the heat. The maximum demand of 8,400 kw is at approximately 85 per cent power factor or 9,900 kva. Subsequent to this test and prior to the installation of

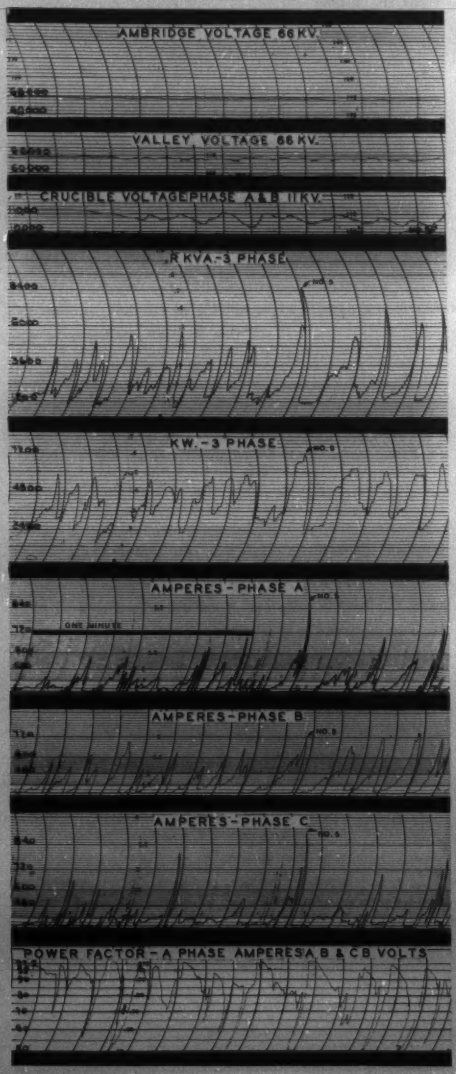


Figure 8. Graphic charts taken 14 minutes after start of heat

The swings have become less frequent, but are greater than shown on figure 6

Figure 9 (below). Oscillograph film taken 14 minutes after start of heat

The currents have become more stabilized than in figure 7. The arc did not completely go out during the film

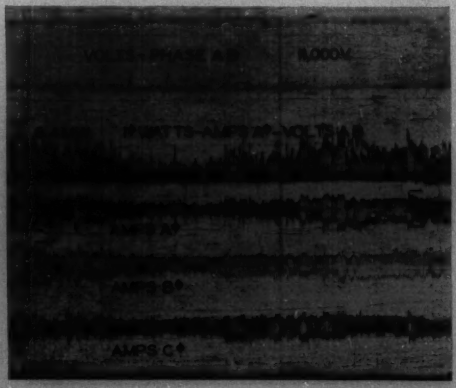


Table II. Pittsburgh Crucible Steel Company, Midland, Pa.

April 10, 1940

15-Minute Kilowatt Demands

1:30 to 1:45 p.m.	1,800
1:45 to 2:00 p.m.	4,020
2:00 to 2:15 p.m.	3,960
2:15 to 2:30 p.m.	6,720
2:30 to 2:45 p.m.	7,080
2:45 to 3:00 p.m.	8,400
3:00 to 3:15 p.m.	6,480
3:15 to 3:30 p.m.	6,600
3:30 to 3:45 p.m.	3,900
3:45 to 4:00 p.m.	6,960
4:00 to 4:15 p.m.	7,200
4:15 to 4:30 p.m.	3,840
4:30 to 4:45 p.m.	1,680
4:45 to 5:00 p.m.	2,640
5:00 to 5:15 p.m.	1,560
5:15 to 5:30 p.m.	0
5:30 to 5:45 p.m.	1,320
5:45 to 6:00 p.m.	840
6:00 to 6:15 p.m.	1,140
6:15 to 6:30 p.m.	1,200
6:30 to 6:45 p.m.	1,320
6:45 to 7:00 p.m.	360

Next heat started at 7:45 p.m.

Complete heating cycle 6 hours and 15 minutes.

the second furnace the 15-minute demands were somewhat less.

The oscillograms showed maximum amperes of 840 while the graphic charts gave maximum values of 1,100. Probably the true maximum lies between the two, in so far as the graphic meters would probably overswing and the maximum values were probably not recorded on the oscillograph film.

Test on Two Furnaces

Following the installation of the second furnace, test data were obtained of the two furnaces melting simultaneously at the highest secondary voltage. Graphic meter chart records only of voltage, amperes, etc., the same as for the first furnace were obtained. Time has not permitted the preparation of the exhibits for inclusion in this paper but they will be available at a later time for discussion purposes.

During the test, number 2 furnace was melting the initial charge and number 1 furnace was melting the "back charge." Number 2 furnace started the initial melt down 29 minutes prior to number 1 furnace starting the melt down of the "back charge." The test continued from the time number 2 furnace started the melt down of the initial charge until the initial charge was melted, approximately 1¾ hours. The 11-kv bus tie was closed during the test to facilitate the obtaining of the records.

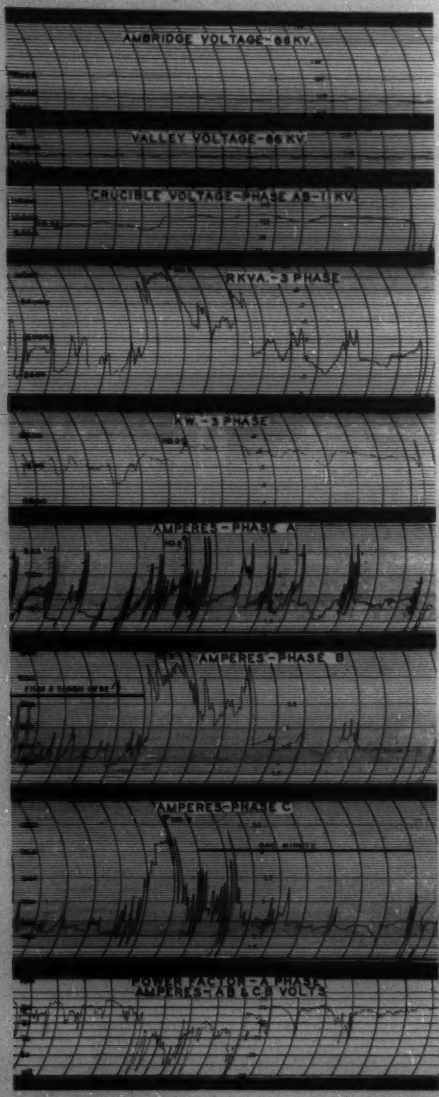


Figure 10. Graphic charts one hour after start of heat

Large furnace swings probably caused by scrap falling against electrodes or falling into molten metal raising its level and short-circuiting the electrodes

Figure 11 (below). Oscillograph film taken during time of figure 10

The exact correlation is not known

Results

The maximum combined instantaneous load swing of the two furnaces, lasting a fraction of a second, amounted to 10,580-kva, 3 phase with a calculated power factor of approximately 52.0 per cent (change in load). The next largest swing amounted to 7,500 kva, 3 phase and all other swings were materially less than 7,500 kva.

The maximum instantaneous load of seconds duration was found to be 22,850 kva, and there were several near this value.

Based upon maximum load swings (10,580 kva) the voltage flicker would exceed that of one furnace by about 20 per cent. However, the combined load swings of the two furnaces were much less frequent than for one furnace and actually there seemed to be no flicker

problem. Voltage regulation was of course greater but not intolerable.

The maximum 15-minute kilowatt demand was 15,600 at approximately 75 per cent power factor or 20,800 kva.

The graphic charts show maximum amperes of 1,590 per phase in the 11-kv circuit. Due to the larger ammeter constant, overswinging did not seem to be as pronounced as in the initial furnace test.

References

1. Arc-Furnace Loads on Long Transmission Lines, T. G. LeClair. AIEE Transactions, volume 59, 1940 (April section), pages 234–9.

2. Industrial Electric Heating—Transformers and Reactors for Three-Phase Arc Furnaces, N. R. Stansel. *General Electric Review*, May 1937.

3. Power Company Service to Arc Furnaces, L. W. Clark. AIEE Transactions, volume 54, 1935 (November section), pages 1173–8.

4. Three-Phase Electric Arc Furnace, Samuel Arnold. AIEE Transactions, volume 52, 1933, pages 839–43.

5. Modern Electric Furnace Design and Practice, H. F. Walther. Presented at the 36th Annual Convention Iron and Steel Exposition, Association of Iron and Steel Engineers, Chicago, Ill., September 24, 1940.

6. Application of Large Phase-Shifting Transformer on an Interconnected System Loop, W. J. Lyman and J. R. North. AIEE Transactions, volume 57, 1938 (October section), pages 579–87.

7. Controlling the Power Flow in a 300-Mile Transmission Loop, W. J. Lyman and J. T. Mercereau. *Electrical Journal*, October 1938.

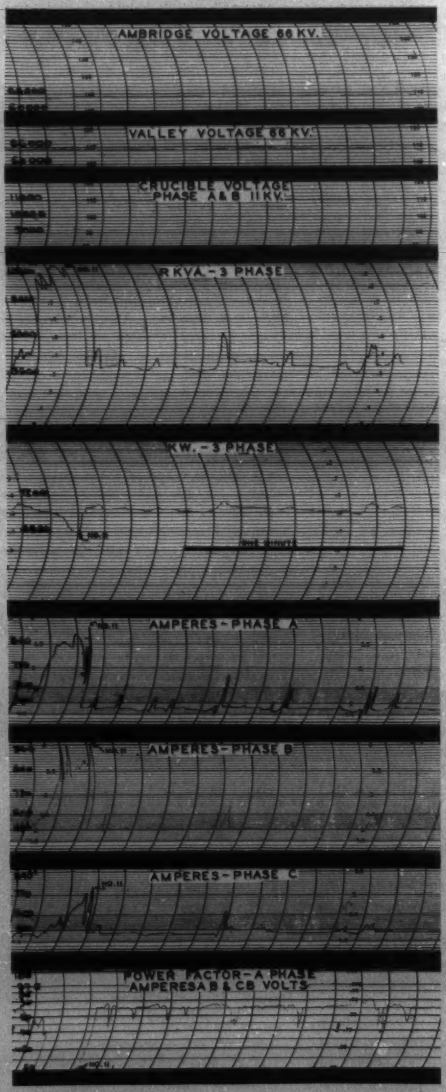

AMBRIDGE VOLTAGE 66 KV.
VALLEY VOLTAGE 66 KV.
CRUCIBLE VOLTAGE PHASE A & B 11 KV.
R KVA. - 3 PHASE
KW. - 3 PHASE
AMPERES - PHASE A
AMPERES - PHASE B
AMPERES - PHASE C
POWER FACTOR - A PHASE AMPERES A B & CB VOLTS

Figure 12. Graphic charts 1½ hours after start of heat

The large load, point 11, was probably caused by scrap falling into molten metal and raising its level

Figure 13. Graphic charts during refining period

A timing device cut off the meters at 4:30 p.m.

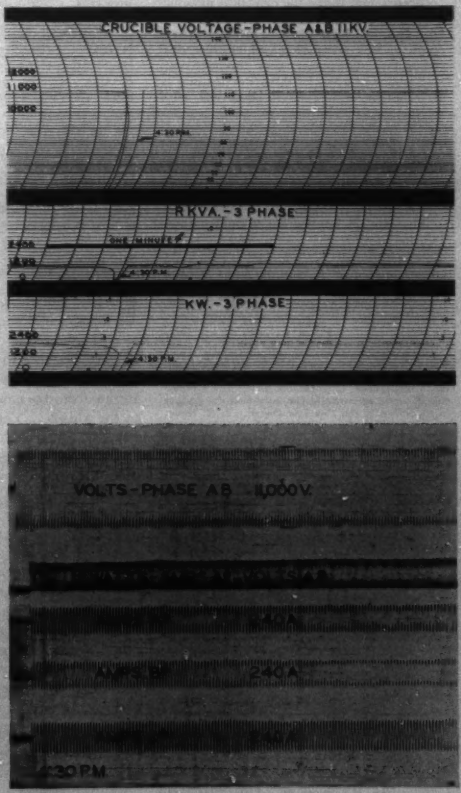


Figure 14. Oscillograph film taken during refining period, corresponding to figure 13

The timing device was operated at the extreme left

The "Electrogear"—A New Electromechanical Vehicle Drive

ERNST WEBER
FELLOW AIEE

Synopsis: Within recent years a new electromechanical transmission known as the "Electrogear" has been developed for use in gas and Diesel engine cars of all types including busses, trucks, rail cars, and track-laying vehicles. The paper describes the principle of its operation which is basically a differential action between direct mechanical power transmission and a generator-motor system, interlinked by means of a permanently engaged planetary differential gear.

At the start, both the electrical and mechanical power flows are in the same direction, giving high torque multiplication. As the vehicle speed increases, the electrical power flow diminishes, goes through zero, and finally reverses its direction, leading to high speed, low torque operation with "overdrive." The torque ratio is thus continuously variable as in the gas-electric drive, and is controlled independent of road conditions by a small auxiliary generator which acts as the "brain" of the system. The design and installation of one specific Bus Electrogear is given in detail in order to illustrate the application to public transportation, though various other models have been built and demonstrated. Extensive test data graphically describe the superior performance of this new vehicle drive which combines the ideal flexibility and low maintenance cost of the gas-electric drive with the economy of the standard gearshift transmission. Actual operation requires only accelerator and brake, both acted on conventionally by means of the conventional pedals, and a selector switch with engine starting, forward and reverse positions. The engine speed varies continuously, and due to the fact that only a comparatively small part of the engine power is circulated through the electrical machines, the weight of the drive is about one-half of that of the gas-electric transmission. Since the Electrogear goes automatically and inherently into "overdrive" at higher car speeds on level road, and can be designed to keep the engine speed in its most economic range during the major part of full throttle acceleration, its fuel economy is at least as good as that of the standard gearshift transmission, and for heavy city schedules becomes even considerably better.

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1. For all numbered references, see list at end of paper.

I. Introduction

EVER since internal combustion engines have been used for the propulsion of vehicles, attempts have been made in great number to overcome the fundamental problem of flexible transmission of torque from the gasoline or Diesel engine to the wheels.[1] Yet no practical solution has been found which merely by mechanical devices produces a continuously variable ratio between engine torque and driving torque and is controlled by the action of the driver of the vehicle.

One of the most unsatisfactory elements of the standard gearshift transmission is the mechanical clutch operated by a separate clutch pedal. Practical ways have been found now to replace this clutch by a hydrodynamic coupling or "fluid flywheel"[2,3] which essentially consists of two rotating vane systems; one connected to the driving shaft, acting as centrifugal pump, and frequently called the impeller; the other connected to the driven shaft, acting as a turbine, and frequently called the runner. Torque transmission is obtained by the fluid circulating through both sets of vanes whereby on account of friction losses a certain amount of slip occurs. Any change in impeller speed causes a corresponding but slightly lagging change in runner speed resulting in a smooth operation of the vehicle without jolts. Since this "fluid flywheel" only acts torque transmitting, it must be used in connection with torque multiplying gears, either manually operated as in Chrysler cars, or in connection with automatic gearshifts as in the "hydra-matic" drive of the Oldsmobile[4] or it can be combined with a semi-automatic transmission as the "Fluid-gear" developed jointly by the A.C.F. Motors Company and the Spicer Manufacturing Company.[5]

A further step is the hydrodynamic transmission or "torque converter",[3,6] this device adds a stationary vane system to the hydrodynamic coupling as a reaction member changing the tangential velocity of the fluid and thus produces torque multiplication. As the vehicle starts, maximum torque multiplication is obtained with a slip of 100 per cent between impeller and runner, and as the vehicle speed increases, slip and torque multiplication decrease. At a predetermined speed of about 17 miles per hour, direct mechanical drive is established automatically, without action of the driver. Obviously, the efficiency and fuel economy in the hydrodynamic range of driving is considerably lower than in the standard gearshift transmission, though the acceleration can be made to be satisfactory.

In spite of this variety of more or less automatic transmissions now available,[7] none of these can truly lay claim to be the

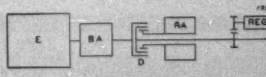


Figure 1. Schematic diagram of Electrogear

BA, RA, REG—Armatures
D—Planetary differential gear
E—Engine
OS—Output shaft

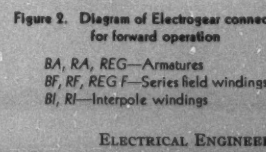


Figure 2. Diagram of Electrogear connections for forward operation

BA, RA, REG—Armatures
BF, RF, REG F—Series field windings
BI, RI—Interpole windings

ultimate solution of the fundamental problem of power transmission in individual vehicles as recently admitted by high authority in the automotive industry.[7a] The only and earliest solution outside the field of strictly mechanical means is the well-known gas-electric transmission in which the engine drives a generator at nearly constant speed and one or two motors are coupled to the driver axle. This gas-electric transmission has recently been considerably improved[8,9] and would appear to be the ideal solution since it gives a continuously variable torque ratio, were it not for the large loss of efficiency and the large size and weight of the electrical machines needed to carry the whole engine power.

The purpose of this paper is to describe the progress in the development of an entirely new principle of power transmission,[10] invented by A. H. Neuland[11] and developed during recent years through the support of The Power Transmission Company of New York City, owners of the patents. Fundamentally, it constitutes an electromechanical drive and is based upon a differential action between directly transmitted mechanical power and d-c electric power furnished by one electrical machine and consumed by another. The driving torque and therewith the torque ratio is controlled by conventional use of the accelerator pedal, and its variation is produced by a small auxiliary generator whose speed is proportional to vehicle speed. Since the transmission embodies electrical machines connected through the elements of a differential gear of the planetary type, the name "Electrogear" has been adopted for it.

The Electrogear has the extreme flexibility of the electric drive and, like this, gives a continuously variable torque ratio. In addition, it has the advantage of high fuel economy, since only a fraction of the mechanical power is transformed into electric power, and since the engine speed though variable can be kept within its most economic range even at the highest vehicle speeds, when overdrive automatically occurs. On account of the partial conversion into electric power, the sizes and weights of the electrical machines are considerably smaller than in the gas-electric drive with the attending advantages of lower currents and smaller commutators.

Designs of the Electrogear have been made and demonstration models built for several 5-passenger cars, for a 36-passenger city bus, and for a 12-ton track-laying vehicle. The Pittsburgh Testing Laboratory made extensive road tests of a five-passenger sedan with the Electrogear drive, and then duplicated the same tests of the same car with its conventional gearshift drive. The comparative results covered in a report[16] should be of interest to the automotive industry as well as to electrical engineers since they show that a transmission using electrical machines in proper combination with a differential gear can be just as efficient as a purely mechanical transmission.

The detail discussions in this paper however pertain to the bus application because the greatest variety of drives has been developed in this field, so that comparisons can readily be drawn from available commercial test and performance data.

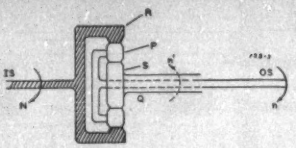


Figure 3. Planetary ring gear differential

R—Ring gear	*Q*—Quill
P—Planets	*IS*—Engine shaft
S—Sun gear	*OS*—Output shaft

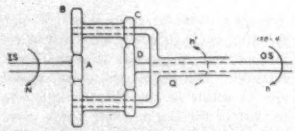


Figure 4. Double-planet differential

A—Input sun gear	*B, C*—Planets
D—Output sun gear	*Q*—Quill
IS—Engine shaft	*OS*—Output shaft

II. Principles of Operation and Design

Figure 1 is a schematic sketch of the Electrogear drive with only the armatures of the electrical machines indicated for simplicity, figure 2 shows the connection diagram for forward operation of the vehicle, and figure 3 gives a more detailed sketch of the differential gear. The armature *BA* of the one electrical machine is directly coupled to the engine shaft *IS* and the ring gear *R* of the differential gear; this machine may, for convenience, be called booster. The armature *RA* of the second electrical machine is coupled to the sun gear *S* of the differential gear and usually is mounted on a hollow shaft or quill *Q;* this machine may, for convenience, be called reducer. Booster and reducer are series-wound d-c machines, both connected in series for forward operation of the vehicle as seen in figure 2. The auxiliary generator has its armature *REG* driven by suitable gears or by belt from the output shaft *OS*, which in turn carries the planet spider with the planets *P* of the differential gear. This auxiliary machine, called regulator for convenience, is connected parallel to the booster field; its function is the distinctive feature of the Electrogear.

1. Operation of the Electrogear

In forward operation, with the vehicle standing still and the engine idling, the ring gear and booster armature *BA* will turn with engine shaft speed, whereas the planet spider and output shaft are at rest. Thus, the sun gear with the reducer armature *RA* has to turn in a direction opposite to engine shaft rotation. Now, the electrical machines are so connected that under these mechanical conditions the reducer will act as self-excited generator and feed current into the booster, which will act as motor permitting just enough current flow to maintain polarities without moving the vehicle.

Depression of the accelerator pedal increases the engine speed and power and therefore the electric power generated by the reducer which drives the booster as motor in the same direction of rotation as the engine. Thus, the ring gear torque is actually the sum of engine and booster torques. Since both ring gear torque and reactive torque of reducer act in the same direction upon the planet spider, a considerable driving torque multiplication takes place comparable to "first gear" in mechanical transmissions; the planet spider starts revolving and the vehicle starts moving. As the vehicle, and with it the planet spider, speeds up, the reducer slows down so that without any further action the vehicle could reach only a comparatively low speed determined by the electromechanical balance of torques.

However, part of the main current is shunted through the regulator which has its field so connected as to generate a voltage in opposition to the voltage drop across the booster field. Since the regulator speed increases with vehicle speed, the regulator voltage also increases and eventually reverses the current in the booster field. The electrical design must, of course, correlate this period with the period in which the reducer has slowed down enough to be unable to drive the booster as motor, so that the regulator, furnishing from now on the field excitation of the booster in reversed direction, forces it to act as generator. With the main cur-

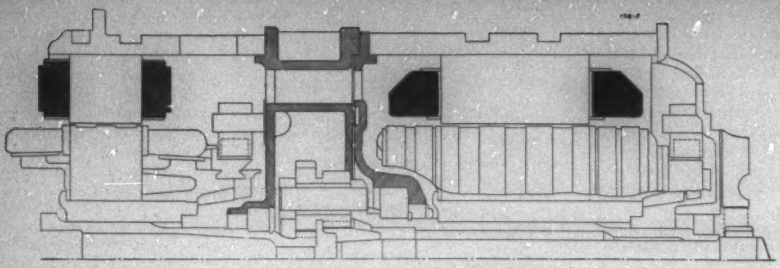


Figure 5. Simplified drawing of Electrogear layout for a city bus

rent continuing to flow in its original direction, the reducer must now reverse its direction of rotation to run as motor. It is quite obvious, at this point, that the regulator is the automatic governor of the booster and determines the over-all action of the electrical power flow which is differentially superimposed upon the mechanical power transfer. Since, in operation, the transitions from motor-to-generator state and vice versa are accomplished smoothly and without any interruption, the resulting variation in driving torque is also continuous and responsive to the degree of depression of the accelerator pedal which, in fact, is an inherent feature of this transmission.

As soon as the reducer reverses its direction of rotation, all three elements of the differential gear, namely ring gear, planet spider, and sun gear are rotating in the same direction. Obviously, at some particular vehicle speed the differential gear will rotate as a solid unit in which case the torque ratio between input and output must be unity, corresponding to "high gear" in the usual mechanical transmission. Advantageously, one can choose to have this occur well below top speed of the engine, preferably close to the most economic speed of the engine with respect to fuel consumption. Further increase of vehicle speed automatically brings about the condition of "overdrive," since the regulator output also increases and forces the booster to generate an increasing voltage at almost constant speed, which in turn speeds up the reducer as motor; thus the ratio of engine to vehicle speed decreases to a value below unity, which is determined primarily by the amount of conversion into electric power at top speed of the vehicle.

Reverse operation of the vehicle is obtained as in any electric drive by reversing the fields of both booster and reducer with the regulator disconnected from the booster field. The booster now acts as self-excited generator driven by the engine and the reducer runs as motor, speeding up in its idling direction of rotation which is opposite to engine shaft rotation. This forces the planet spider also to rotate in the direction opposite to that of the engine shaft which gives backward motion of the vehicle. The maximum reverse speed is of course limited by the electromechanical torque balance under these conditions but is sufficient for all practical purposes, since the maximum tractive effort in reverse operation is as high as 60 to 65 per cent of that in forward operation.

2. Special Features of the Design

The design of this electromechanical transmission requires a careful study of the interrelation of all component elements in order to obtain proper functioning and the economy in weight and cost which is all important for any vehicle drive. The choice of the rear axle ratio (for rear axle drive) and that of the ratio in the planetary differential are interdependent and are determined by the desired rate of initial acceleration and by the top speed of the vehicle. As mentioned above, the fuel economy can be influenced decisively by proper choice of the vehicle speed in full throttle acceleration at which "overdrive" sets in; in this respect particular attention has to be paid to the auxiliary generator or regulator. For best results, individual designs are desirable for different performance requirements, though within any particular class of vehicle a standard design can be used for the average requirements and adjustments made by the use of slightly different rear axle ratios as is customary with the standard mechanical transmissions.

The planetary differential gear of the ring gear type is most commonly used in vehicle drives. Referring to figure 3 and denoting with r the ratio of the number of ring gear teeth to the number of sun gear teeth one finds for the ratio G of the torques on output and input shafts the value

$$T_{OS}=\frac{r+1}{r}T_{IS}=GT_{IS} \qquad (1)$$

Obviously, the largest value of G is obtained for the smallest value of r; for mechanical reasons, therefore, $G \leq 1.8$ which restricts this type of planetary differential to use in vehicles with low torque multiplication, as for example in passenger cars.

In order to obtain larger torque multiplication, a differential gear of the type shown in figure 4 and known as "reverted train" has to be used; on account of the two sets of planets it is often called double-planet gear. For reasons of con-

Figure 6. Photographic view of Electrogear on the dynamometer stand

struction the ratio of teeth in B to A is usually the same as that in D to C, and denoting it as q, one has for the torque ratio G of output to input shafts

$$T_{OS} = q^2 T_{IS} = G T_{IS} \qquad (2)$$

This type of planet gear can, therefore, be used for any large torque multiplication within practical values, and has the further advantage that the quill Q carrying the reducer can be located either to the left or to the right of the planet gear. It has been applied in the bus drive and the drive for the track-laying vehicle.

The main electrical machines have to be designed with utmost economy in the use of materials. In a bus drive with a definite schedule the power requirements can easily be evaluated; the effective mean value of the losses with proper consideration of cooling conditions at the various vehicle speeds will lead to the customary one-hour rating as a basis for the design. In the case of vehicles for general service suitable assumptions must be made with respect to most frequent driving conditions and maximum possible overloads. In the designs built for the bus and track-laying vehicles glass insulation was used throughout to take full advantage of the maximum temperatures permitted by AIEE Standards for traction machines. Of course, only experience can tell what effective cooling the machines may have on account of their particular location on the moving vehicle. The test data below will illustrate these points more fully.

The most important element in the Electrogear transmission is the regulator since it determines and controls the operation of the booster as motor or as generator. Being connected in parallel to the booster field, it carries a large part of the main current in addition to the current which it produces by self-excitation. Furthermore, its magnetic characteristic must be such that at the highest vehicle speeds it will not, or only slightly, saturate in order to provide adequate excitation for the booster. Since it is a very low voltage machine, care has to be taken to obtain good commutation under all driving conditions. All these are requirements that can easily be satisfied by an adequate design, but they are quite different from those met with in the design of general purpose machines.

3. Example of Installation

As an illustration the Electrogear designed for an A.C.F. bus weighing 14,220 pounds empty and 19,420 pounds with seated load will be described. The basic data for the bus were furnished by the engineers of The J. G. Brill Company at

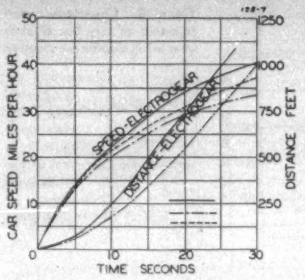


Figure 7. Full throttle acceleration of city bus

——— Electrogear
— · — · — Gas-electric
– – – – – – – Gearshift

Philadelphia. The bus was to be equipped with a Hall-Scott 135 engine mounted under the floor and delivering 116 brake horsepower at 2,000 rpm of which approximately 9 horsepower were used in accessories so that only 107 horsepower were available for the transmission. As a city bus the requirements were assumed to be 10 stops per mile, 11 seconds for each full stop, a scheduled speed of 11 miles per hour and acceleration up to 25 miles per hour between stops. The one-hour ratings of the electrical machines were—

Booster as motor
.....22.5 horsepower at 1,900 rpm
Reducer as generator
.....20 kw at 1,200 rpm

with maximum speeds of the booster about 2,600 rpm, of the reducer about 2,200 rpm; each had four main and four commutating poles, was series wound and designed for optimum voltage from the point of view of economy. Both main machines as well as the regulator were built and individually tested by the Delco Products Division of General Motors Corporation at Dayton, Ohio.

The mechanical layout was primarily determined by the available space between engine shaft flange and universal joint of the propeller shaft in the standard bus chassis. This put a limitation upon the axial extension of the armature end connections, but by placing the planet gear between booster and reducer and shortening the propeller shaft a solution was found satisfactory from all angles. The planet gear is of the double-planet type and uses the smallest feasible sun gear on the input side in order to utilize the space between the two main machines most economically. The complete layout, in simplified lines shown in figure 5, was made by The Timken-Detroit Axle Company, who also designed and built all mechanical parts and assembled the complete unit for installation. As seen, the assembly is extremely compact and utilizes the space within the bell housing, it provides excellent paths for the cooling air which is supplied through air cleaners, and it gives easy access to all brushes for examination and service. A photographic view of the assembly given in figure 6 shows the mounting on the dynamometer stand during preliminary tests. The mechanical construction also involves the brake drum as an integral part of the output shaft flange. Oil seals are incorporated in suitable form and number to insure proper local lubrication without permitting oil to enter into the electrical machines.

The actual weights (in pounds) of the various parts were as follows:

Booster (complete with shaft)	393
Reducer (complete with quill)	534
Regulator (complete with drive)	82
Planet gears	18
Electric control (complete without cover and brake resistor)	56
Air cleaners and miscellaneous parts	29
Total weight	1,112

Inasmuch as this was a sample unit and time was of essence, the material and dimension specifications of the design were not followed closely, so that the above actual weights of the booster and reducer exceeded the computed weights by about 150 pounds. Therefore the given weights do not in any sense constitute the most economic construction.

The electrical control[12] consists principally of a selector switch which connects the electrical machines for the three distinct operations: engine starting, forward, and reverse; and several relays which reduce the effort of the driver to a minimum, namely conventional operation of accelerator and brake pedals, and at the same time provide appropriate interlocks. The control equipment was designed with the co-operation of, and furnished by, the Ward Leonard Electric Company of Mount Vernon, New York.

The "starting" relay is operative only in the "engine starting" position of the selector switch and by interlock only when the accelerator pedal is depressed so as to avoid an accidental short circuit of the battery over the main circuit. Depression of the start button connects the conventional starting motor to the battery to start the engine and also sends current through the booster armature and the booster and reducer main fields in series, establishing the proper polarities for operation in either forward or reverse

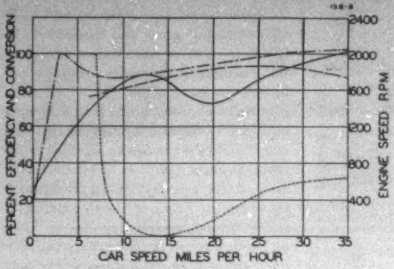


Figure 8. Characteristic performance of city bus Electrogear in full throttle acceleration

— · — · — Gas-electric engine speed
———— Electrogear engine speed
– – – – – – – Electrogear conversion ratio (per cent of engine power)
— — — — Electrogear efficiency (driver to engine)

direction. This is entirely sufficient for all subsequent operations of the vehicle and no further teasing of the generator is required at any time.

With the selector switch in forward position, depression of the accelerator pedal operates the "accelerator" relay, which permits the reducer to build up self-excitation as generator and to accelerate the vehicle as previously described.

In order to provide the very desirable benefits of electrodynamic braking, the brake relay connects a brake resistor parallel to the two main armatures as soon as the brake pedal is slightly depressed, whereas full depression applies additionally the air brakes. Again, an interlock prevents simultaneous accelerating and braking by de-energizing the accelerator relay when the brake pedal is depressed.

As a protective feature a temperature-operated contact system is inserted close to the reducer main field. Should the temperature of the field coils exceed a critical value, these contacts open and prevent further operation of the accelerator relay and thus of the Electrogear until the electrical machines have cooled down sufficiently to avoid damage. Though this protector never had occasion to act even during the most severe test runs, there might be conditions of getting into deep ruts or similar difficulties when this feature would prove desirable.

III. Comparative Test Data on Bus Transmission

As mentioned above, the bus transmission was chosen as a representative illustration, because in commercial transportation fuel economy, low maintenance cost, durability, acceleration, gradability, ease of operation, and comfort of the driver are of particular importance. Consequently many attempts have been made to develop a bus transmission which would satisfactorily meet all these requirements. Thus, there are at present in actual use, in addition to the standard gearshift transmission, the torque converter[4] developed by the Spicer Manufacturing Company in collaboration with General Motors Corporation, the "Fluidgear" developed jointly by A.C.F. Motors Company and Spicer Manufacturing Company,[6] and the gas or Diesel-electric drives developed by the General Electric Company[8] and the Westinghouse Electric Manufacturing Company.[9] Both the torque converter and the Fluidgear have somewhat lower performance[12] than the standard gearshift transmission, the first with respect to fuel consumption, the second with respect to acceleration, so that comparison of the Electrogear performance will be made with the standard mechanical and the gas-electric drives.

In comparing Electrogear with gearshift performance it should be borne in mind that the test data available on the gearshift transmission are obtained with a skilled driver and constitute optimum results which are seldom attained in actual commercial service, whereas Electrogear as well as gas-electric test performance is reproducible uniformly with any driver, no skill being involved in the operation of these drives, as they require only conventional use of conventional accelerator and brake pedals.

For a fair comparison of these drives it is also necessary to take into consideration the differences in bus weight on account of the drive. It was agreed by the engineers consulted in the preparation of this paper that all test data should be compared on the basis of the following bus weights; with standard gearshift transmission 18,000 pounds; with Electrogear 18,500 pounds; with gas-electric drive 19,200 pounds.

1. Performance Tests With the Electrogear

During the summer of 1939 extensive tests were run with an A.C.F. bus equipped with the Electrogear transmission and a standard $6^1/_4$ ratio rear axle. In all tests the total weight of the bus was about 18,500 pounds. After preliminary tests had demonstrated the satisfactory over-all performance of the transmission and necessary adjustments had been made, final tests were run with calibrated measuring equipment. All the tests were carried on under the supervision of The J. G. Brill Company's (or A.C.F. Motors Company's) engineers and a representative of the Pittsburgh Testing Laboratory.

The acceleration runs were made on a concrete highway west of Philadelphia, and the average taken for several runs in each direction in order to even out possible differences in slight slopes. Speeds were measured by means of a "fifth wheel," mounted on the side of the bus and driving a Hasler-Tel integrating accelerometer, giving mean speed values for each second. The result is shown in figure 7 where speed and distance are plotted against time. According to the records the Electrogear accelerated to 40 miles per hour in 29.2 seconds, and to a distance of 1,000 feet in 26 seconds, which must be considered excellent for any bus of this size. As mentioned before, the Electrogear performance being inherently automatic it can always be reproduced by drivers without skill or familiarity with the principles of operation.

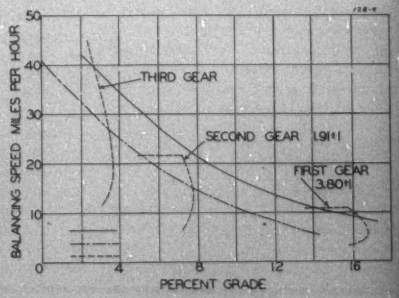


Figure 9. Gradability curves of city bus in terms of balancing speed against per cent grade

———— Electrogear
— · — · — Gas-electric
– – – – – – – Gearshift

From readings of the currents and voltages during acceleration, the circulating electric power can be computed and compared with engine power. The conversion ratio plotted in figure 8 against car speed graphically shows the percentage of engine power which the Electrogear converts into electric power, and checks very well the theoretical values used in the design. It is quite obvious that during the major part of the acceleration period only a very small fraction of engine power is circulated electrically, so that the losses of the double conversion are very small. This is also expressed in the high values of efficiency, defined here as the ratio of power at the wheels to engine power and shown in figure 8. Finally, in the same figure, the engine speed during full throttle acceleration is also given; the moderate values up to 20 miles per hour vehicle speed, in spite of the high rate of acceleration, are indicative of low fuel consumption for heavy schedules.

In normal driving (at constant speed on level road) the above advantages are, of course, much more marked. Thus, in the present installation the "overdrive" becomes noticeable at about 35 miles per hour, i.e., the engine speed is held below the values which the direct drive of a mechanical transmission would require. Equally, the conversion ratio becomes lower than in acceleration, which improves the over-all efficiency particularly at the higher car speeds.

Gradability tests were made on a special test hill near Philadelphia, which is about 700 feet long and has for the major part a grade of 15 per cent, tapering to about 12 per cent toward the top. From a standstill at the foot of the hill the bus was traveling at a speed of 10 miles per hour in less than 15 seconds, and was at the top of the hill at 14.5 miles per hour still accelerating. During this climb the engine speed was very low, with a maximum of 1,650 rpm at the top of the hill. Again, according to the records available to date, this performance was the best obtained on that hill with any bus transmission. On the basis of these and other tests, a gradability curve was computed giving the maximum speed of the bus attainable on various grades; the curve is shown in figure 9.

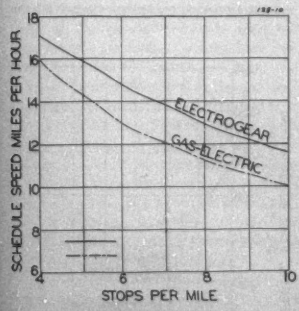


Figure 10. Schedule speed. Stops 11 seconds. Acceleration to about 25 miles per hour

——— Electrogear
— · — · — Gas-electric

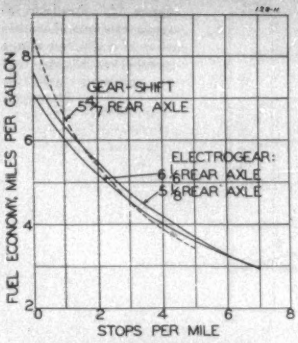


Figure 11. Fuel economy for various stops per mile and different rear axle ratios

——— Electrogear (18,500 pounds)
- - - - - - - Gearshift (19,980 pounds)

In order to check continuous performance and temperatures under severe strain the bus was operated for 3 miles with 13 stops per mile, and after a 5-minute interval for $7^1/_2$ miles with 10 stops per mile and 11 seconds per stop, and acceleration up to 25 miles per hour between stops. At the 114th stop the cooling water of the engine boiled over and the brakes were smoking hot. Yet the temperature of the Electrogear machines measured with thermocouples inserted in the field coils was 25 degrees centigrade for the reducer and 43 degrees centigrade for the booster lower than the permissible maximum temperature. The schedule speed during this breakdown test run, as checked repeatedly, was 11.6 miles per hour, taking 5 minutes 11 seconds for every 10 stops. On the basis of this as well as other tests, the schedule speed for various stops per mile was computed and is shown in figure 10. Gasoline consumption was also measured during the runs, giving 2.67 miles per gallon on this severe schedule.

For comparison with other drives, independent fuel consumption tests were carried on at length, for various stops per mile and acceleration up to 30 miles per hour. Figure 11 shows the results for two different rear axle ratios. It is most interesting to observe that the larger ratio $6^1/_8$ which was chosen in the design actually leads to higher fuel economy at heavier schedules than the $5^1/_8$ ratio, which in turn shows up slightly better up to 6 stops per mile. This justifies the selection of the $6^1/_8$ axle for the originally specified schedule of 10 stops per mile, and illustrates the flexibility of the Electrogear showing that it is easily possible to choose the most economical combination for every operating condition. An Electrogear design made for a schedule of 5 stops per mile shows a fuel economy of 8.5 miles per gallon at 30 miles per hour, and of about 4 miles per gallon at 5 stops per mile, which is considerably better than with the design for 10 stops per mile.

2. Comparison With Mechanical Gearshift Transmission

Through the courtesy of The J. G. Brill Company's engineers comparative test data were made available on the standard gearshift transmission in a bus of about the same seated weight and with the same size engine as used for the Electrogear. The ratios in the gearshift transmission were 3.80 for low gear, 1.91 for intermediate, and $5^4/_7$ for the rear axle. The acceleration curves were referred by adjustment of the acceleration rates to the comparative test weight of 18,000 pounds stipulated for the bus with the gearshift drive. The result is plotted in figure 7, demonstrating the superiority of the available continuous driving torque in the Electrogear as compared with the twice interrupted power flow in the gearshift transmission, which in spite of the almost equal initial acceleration rate causes a loss in momentum serious enough to affect the performance. This can be seen very much better in figure 12 in which the available instantaneous acceleration rates are plotted against car speed, and the vertical dotted lines represent the necessary interruptions in acceleration during the shifting of gears. Though the effect is pronounced in acceleration from a standstill, it is much more impressive when accelerating from a given car speed. Thus at 20 miles per hour the mechanical gearshift can produce only 0.76 mile per hour per second acceleration without shifting to second gear, whereas the Electrogear can deliver 1.52 miles per hour per second by mere normal use of the accelerator pedal.

The comparative gradability is plotted in figure 9 in terms of balancing speed, and demonstrates a further advantage of

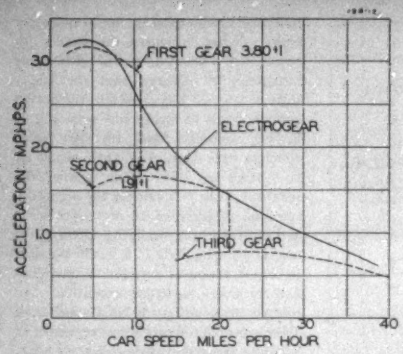


Figure 12. Available instantaneous rate of acceleration of a city bus with a gearshift transmission (- - - -) as compared with the Electrogear

the Electrogear in hilly terrain where the loss of momentum during back shifting of gears is particularly annoying and traffic delaying. Thus, while the standard gearshift bus climbs a grade of only 3.5 per cent at 25 miles per hour, the same bus with an Electrogear will climb a 6.6 per cent grade at 25 miles per hour, which is important with respect to schedule speed on routes with grades. Obviously, this free availability and automatic adjustment of driving torque under all circumstances also indicates a considerable saving in fuel consumption for vehicles traveling in hilly country.

Though no curves are available to show the schedule speed of the gearshift bus directly, reference can be made to an available actual service comparison with the gas-electric drive,[14] which shows that at about the same acceleration rate the gearshift bus schedule is about six to eight per cent slower than that of the gas-electric bus. Since the Electrogear, as shown in figure 7, has better acceleration than the gearshift transmission, the difference in schedule speed in favor of the Electrogear bus would be even greater. At that, it should be kept in mind, in comparing the acceleration curves, that in the case of the gearshift transmission they are obtained with the best driver continuously using extreme care in shifting at the proper moment; such ideal conditions, however, cannot be continuously reproduced in actual service, so that actual schedule speed with gearshift transmissions (manual or automatic) must be lower than theoretically expected, whereas, as pointed out, the Electrogear performance is not dependent on driving skill for uniform efficiency.

In order to compare fuel consumption for various stops per mile and acceleration up to 30 miles per hour, figure 11 shows in dotted line latest data obtained by The J. G. Brill Company on a bus weighing 19,980 pounds and using the same type engine as the Electrogear bus. Since fuel consumption is not proportional to bus weight, reference cannot easily be made to the comparative weight of 18,000 pounds; however, it is quite apparent that the repeated shifting of gears decreases relatively the fuel economy at the heavier schedules, bringing it into the range and below that of the Electrogear beyond about five stops per mile. The influence of shifting gears can best be seen in figure 14 in which the specific fuel consumption for full throttle acceleration is plotted against bus speed, based upon a typical fuel consumption curve of the Hall-Scott 135 engine shown in figure 13 and the engine speed variation shown in figure 8 for the Electrogear, and computed from the gear ratios for the gearshift bus. Over the entire range from 5 to 26 miles per hour (the speed most frequently used in city service) the Electrogear designed for heavy city service keeps the engine in the range of lowest possible fuel consumption. Flexibility of the Electrogear design makes equal or better fuel economy available in busses with lighter city service or for intercity use. In general, then, the Electrogear proves to be at least as efficient as the gearshift drive, and for any particular operating requirements can be made more economical. This clearly shows that the low efficiency of electric drives disappears when the electrical machines are used in proper combination with mechanical elements.

3. Comparison With the Gas-Electric Drive

Through the courtesy of the General Electric Company the performance data of a gas-electric transmission using the same Hall-Scott 135 engine as the Electrogear and the standard gearshift transmission were made available, so that a direct comparison is possible. On account of the greater weight of the gas-electric drive the test weight of the bus in this case was 19,200 pounds. The shunt-wound generator is of the type *GT* 1501 and has a net engine power of 107 horsepower at 2,000 rpm; the series-wound motor is of the type *GE* 1205; the rear axle ratio is $6^1/_8$, comparing with $6^1/_8$ for the Electrogear.

The speed-time curve of figure 7 indicates that the gas-electric acceleration is considerably less than that of the Electrogear, especially at car speeds beyond about eight miles per hour. This is easily accounted for by the fact that for city bus installation the Electrogear is designed to have very little engine power circulating through its electrical machines between 8 and 24 miles per hour car speed, as seen from figure 8, so that there is hardly any conversion loss in that range of car speed. On the other hand in the gas-electric drive the electrical machines continuously carry all the available power so that a considerable conversion loss is sustained. The same explanation holds, of course, for the divergence of the distance-time curves, also shown in figure 7.

For the same reason, the gradability of the Electrogear is considerably higher than that of the gas-electric drive using the same engine, as seen in figure 9, where the balancing speeds are plotted against per cent grades. However, these curves also illustrate particularly well the singular advantage of a continuously variable torque ratio; namely, to permit considerably higher speeds on grades on which the mechanical drive must shift gears and thus lose momentum. Thus at 15 miles per hour car speed the bus with mechanical transmission can climb only a 3.5 per

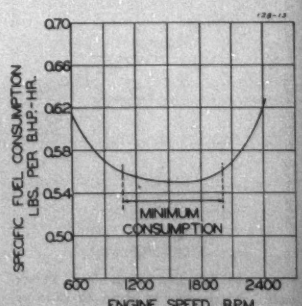


Figure 13. Specific fuel consumption of Hall-Scott 135 engine for full throttle setting

cent grade, the gas-electric bus about a 7.7 per cent grade, and the Electrogear bus even an 11 per cent grade as demonstrated in tests.

Figure 10 shows that the schedule speed of the gas-electric drive is about 1.6 miles per hour lower than that of the Electrogear, assuming 11-second stops in each case. Obviously this difference is due to the considerable difference in acceleration rates already pointed out in connection with figure 7.

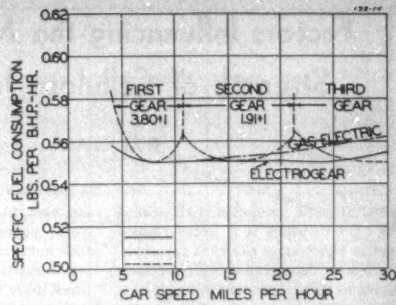
Comparison of the fuel consumption per engine horsepower-hour is plotted in figure 14 on the basis of the full throttle specific fuel consumption of the engine given in figure 13 and of the engine speed curves for the various drives. For the gearshift the engine speeds are computed according to the gear ratios with the assumption that shifting is done when the engine speed reaches 2,000 rpm. For the gas-electric drive the engine speed variation was supplied with the performance data as plotted in figure 8 for comparison with the actual engine speed in Electrogear performance. Figure 14 shows the fuel consumption per engine horsepower-hour in full throttle acceleration to be as follows: highest with the gearshift drive (due to the fact that the engine goes through its entire speed range for each gear ratio); up to 12 miles per hour the same with the Electrogear as with the gas-electric drive; lowest with the Electrogear above 12 miles per hour; since the Electrogear uses much less engine power under all conditions it is evident that its total fuel consumption in full throttle acceleration must be the lowest.

Though no curves are available which would permit a direct comparison of the total fuel economy in commercial service of the gas-electric drive with that of the Electrogear, one can judge from comparisons of the gas-electric drive with the equivalent gearshift transmissions obtained in actual operation[14] that the average fuel consumption of the gas-electric drive is about 20 per cent higher if the acceleration is about the same in both cases. The gas-electric total fuel consumption should be even higher in comparison with the Electrogear since it has been established by tests that in a schedule of five stops per mile or more the Electrogear city bus is even more economical than the gearshift bus.

IV. Summary

The five principal requirements of an ideal power transmission from the gasoline (or Diesel) engine to the driver axle of a vehicle can be formulated as: first, a continuously variable torque ratio; second, effective loading of the engine under all driving conditions; third, uniformly economic operation at all vehicle speeds; fourth, driving ease; fifth, durability and low maintenance.

Figure 14. Comparative fuel consumption per engine horsepower-hour of city bus in full throttle acceleration



The Electrogear has demonstrated that it satisfies all of the above requirements to a higher degree than any known mechanical, hydraulic, or electrical transmission. There is no loss of momentum as in shifting gears, and the engine is never disconnected. Effective engine loading and "overdrive" are inherent features, fully automatic without any facilitating device. The all-around performance of the Electrogear as demonstrated by the Philadelphia tests is superior to that of other known transmissions, and it is significant that the best performance is always automatically produced without calling for skill or judgment. The driver has only the conventional accelerator and brake pedals to use in a conventional way, he has nothing to think about and no controls to manipulate. The durability and low maintenance cost of electrical machines are sufficiently well established by the gas-electric drives still in operation with 400,000 miles or more to their credit. Auxiliary electrodynamic braking (to reduce brake maintenance cost), particularly valuable in busses with heavy city schedules, can easily be made available with the Electrogear.

The design of the Electrogear is simple and flexible, permitting adaptation to any type vehicle. In large vehicles using conventional gas-electric or automatic multishift drives the Electrogear saves space, weight, fuel, and possibly initial cost. Its comparatively low weight opens a wide field of application in medium and light-weight vehicles in which automatically variable infinite ratio transmissions are desirable. To be simple, such transmissions must be electrical.[14] It is not possible to simulate even by complicated mechanical devices all the desired transmission characteristics which are normally inherent in electric drives. Attempts by mechanical engineers to do so have resulted in increasing the weight and cost of mechanical transmissions to an extent approaching the Electrogear in large production.

Bibliography

1. Automatic Transmissions, **P. M. Heldt.** *Transactions S.A.E.*, volume 32, 1937, page 206.

2. Fluid Flywheels, **P. M. Heldt.** *Automotive Industries*, volume 80, 1939, page 109.

3. Hydrodynamic Power Transmission for Motor Cars, **W. Spannhake.** *Journal S.A.E.*, volume 45, Transactions section, October 1939, page 433. Also *Transactions S.A.E.*, volume 34, 1939, page 433.

4. Trends in Design of 1940 Cars, **Th. A. Bissell.** *Journal S.A.E.*, volume 45, Transactions section, November 1939, page 461. Also *Transactions S.A.E.*, volume 34, 1939, page 461.

5. Fluidgear, **C. O. Guernsey.** *Bus Transportation*, volume 18, 1939, page 466.

6. New Hydraulic Drive of Yellow Coach Corporation, **G. A. Green.** *Bus Transportation*, volume 18, 1938, page 448A. Also *Automotive Industries*, volume 79, 1938, page 438.

7. Power Transmission for Busses, **G. A. Green** *Journal S.A.E.*, volume 46, Transactions section, 1940, page 1.

7a. As in 7, page 16.

8. Electrical Drive Provides Automatic Transmission for Busses, **J. C. Aydelott.** *General Electric Review*, volume 40, 1937, page 531.

9. Electric Bus Drives Come Back, **C. A. Atwell.** *Electric Journal*, volume 35, 1938, page 181.

10. New Type of Electro-Mechanical Transmission, **P. M. Heldt.** *Automotive Industries*, volume 76, 1937, page 236. Also in *Transactions S.A.E.*, volume 32, 1937, page 206.

11. **A. H. Neuland:** U. S. Patents No. 2,000,786 of May 7, 1935, No. 2,045,197 of June 23, 1936, and numerous other patents owned by The Power Transmission Company.

12. **E. Weber:** U. S. Patent No. 2,179,364 of November 7, 1939.

13. Hydraulic Drives, **E. S. Pardoe.** *Bus Transportation*, volume 18, 1939, page 462.

14. Operating Experiences With Gas-Electric-Drive Motor Busses, **R. H. Stier.** AIEE Transactions, volume 57, 1938 (June section), page 318. Also in *General Electric Review*, volume 41, 1938, page 229.

15. Report on tests of the Electrogear transmission, Pittsburgh Testing Laboratory. March 1937.

Factors Influencing the Mechanical Strength of Cellulose Insulation

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CELLULOSE insulation, like mineral oil with which it is usually associated in high-voltage electrical apparatus, is subject to deterioration in an increasing degree as the temperature of exposure is raised. This deterioration is a manifestation of the chemical instability of the cellulose. For a proper understanding of this change, it must be recognized that the fundamental chemical reactions involved are of two types. There are those changes which result from the oxidation of the cellulose and those which arise from the decomposition of its molecule. These changes are invariably intermingled in the normal commercial use of cellulose dielectric materials. To prevent dangerous deterioration and to secure the maximum service life of cellulose insulation, the effect produced by each type of reaction, the probability of its occurrence, and the means for its control must be carefully evaluated.

In a previous article[1] the author has described the mechanical and electrical changes in cellulose promoted by thermal decomposition in contrast to oxidation effects. It has been shown that cellulose will change mechanically and electrically with accompanying increase in color and acidity when heated at temperatures even as low as approximately 130 degrees centigrade under conditions which exclude the possibility of oxidation. These changes have been attributed to a molecular decomposition of the cellulose which culminates in the active evolution of gases, water, and other volatile products at temperatures above 130 degrees centigrade.

One of the objects of the present paper is to evaluate from the standpoint of mechanical strength those deteriorating changes in cellulose insulation which are caused by oxidation in contrast to those which result from the purely thermal decomposition of the cellulose molecule. Linen capacitor paper and Manila paper are used to illustrate the test results. These papers are selected because of their industrial importance. Other cellulose insulations, as for example kraft paper, have been found to be of similar behavior. The tensile strength of the insulation has been accepted as a gauge of its mechanical properties.

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1. For all numbered references, see list at end of paper.

The Dormant Period

Cellulose insulation when heated actively exhibits evidence of molecular decomposition only after a "dormant" period, the length of which depends on the conditions of the heat treatment. Foremost among the conditions of importance are the temperature applied, the accumulated thermal history of the cellulose, and the presence or absence of an impregnating liquid such as mineral oil. In general, for unimpregnated insulation, gas evolution and other evidence of serious decomposition are observed after about 12 hours of heating at temperatures higher than 130 degrees centigrade. With oil-treated cellulose insulation, the effect of temperature has been more carefully delineated. Figure 1 illustrates for oil-immersed linen paper the length of the "dormant" period within which no gas is evolved at temperatures from 145 degrees centigrade to 200 degrees centigrade.

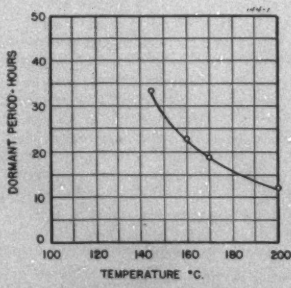


Figure 1. The "dormant" period is the duration of heat treatment which can be applied to cellulose insulation in the absence of oxidation without evolution of gases indicating molecular decomposition

The insulation used is vacuum-dried, oil-impregnated, and oil-immersed linen paper

It is obvious that the single effect of oxidation in promoting cellulose deterioration becomes of major importance only when the effects of molecular decomposition are avoided. It is within this range that the use of an inert gaseous atmosphere such as nitrogen can be expected to have its greatest stabilizing effect. When exposed to more severe conditions of temperature and time so that the "dormant" period is exceeded, molecular decomposition may become the dominant deteriorating factor. Adverse results are produced both directly as a result of pyrochemical change and indirectly because of the corrosive character of the decomposition products formed. It is during this period that the beneficial effects of a nonoxidizing atmosphere such as nitrogen gas are of decreasing, and frequently of negligible, importance.

Conditions Which Affect Aging

When cellulose insulation is exposed to temperatures of normal dielectric use, the rate of deterioration in tensile strength is dependent on the conditions of the heat treatment. Important factors are the temperature applied, the length of the exposure, and the presence or absence of an oxidizing atmosphere. The close intermingling of these factors and the great importance of the first two in producing radical changes in the tensile strength of the cellulose insulation have served to confuse their proper evaluation

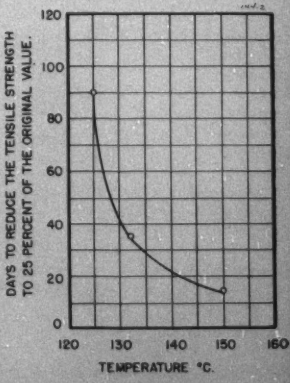


Figure 2. Dry Manila paper will deteriorate mechanically when heated in sealed tubes in contact with nitrogen gas

to the extent that oxidation is frequently looked upon as the fundamental cause of all of the deterioration observed. This is not true, for cellulose insulation will deteriorate even in the complete absence of any oxidizing gas or other source of oxygen. This is illustrated in the data of figure 2. In this series of tests, Manila paper, vacuum dried but not oil impregnated, has been heated in sealed bombs at temperatures from 125 degrees centigrade to 150 degrees centigrade under 250 pounds of dry nitrogen gas. The results are expressed in terms of that period of time necessary to reduce the tensile strength to 25 per cent of the original value. The rapid loss in tensile strength with the increasing temperature of the exposure in nitrogen gives warning against too great an emphasis of the oxidation factor as the fundamental cause of cellulose deterioration.

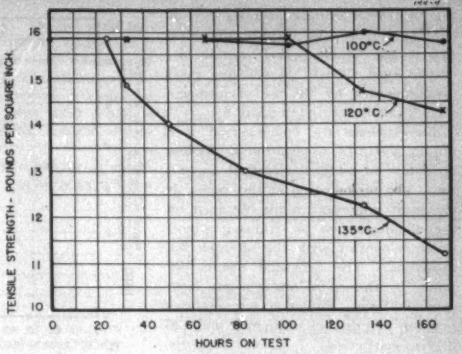


Figure 4. Showing the "stable period" of vacuum-dried, mineral-transformer-oil-treated, and oil-immersed 0.003-inch Manila paper when heated in contact with nitrogen gas

The Stable Period

Available data indicate that, even under the most severe deteriorating conditions, there is an initial period during which the cellulose insulation suffers no loss in tensile strength. During this interval it may even exhibit slight increases. This period has been termed the "stable period." It corresponds to but is not of as great a duration as the "dormant" period discussed in a previous paragraph. After passing through the "stable period" chemical reactions are initiated which affect the mechanical strength of the insulation and which at temperatures above 130 degrees centigrade culminate in the evolution of gases, water, and other volatile products.

The duration of the "stable period" decreases sharply with increased temperature above 100 degrees centigrade. The period of stability is clearly evident in the tests of figures 10 and 11 which describe the behavior of vacuum-dried, oil-treated, and oil-immersed 0.003-inch Manila paper. The "stable period" for each of the relations of figures 10 and 11 is reproduced for purpose of clarity in figures 3 and 4.

The length of the "stable period" is affected by the presence of an oxidizing atmosphere. This is demonstrated in the following data taken from figures 3 and 4.

Test Temperature (Degrees Centigrade)	Length of "Stable Period" in Hours		Per Cent Decrease in Duration of Stable Period Due to Oxidation
	For Run in Oxygen Gas	For Run in Nitrogen Gas	
100	101	168	40
120	33	101	68
135	16	24	33

The effect of oxidation on the duration of the "stable period" of oil-treated and oil-immersed Manila paper decreases as the temperature is lowered. As illustrated in figure 5, at temperatures as low as 85 degrees centigrade, the accelerating effect of oxidation can be expected to disappear. Tests at temperatures in the range of 85 degrees centigrade are of long duration and subject to wide variation, but in general, have served to substantiate this expectation.

When the cellulose is exposed to higher temperatures, the effect of oxidation on the length of the "stable period" does not increase indefinitely. This results because of the increasing importance of the second major factor, molecular decomposition which also greatly affects the rate of cellulose deterioration. The advantageous effect of the presence of nitrogen gas in prolonging the "stable period" of oil-treated cellulose reaches its maximum value at approximately 120 degrees centigrade. With higher temperatures of aging, the pyrochemical decomposition of

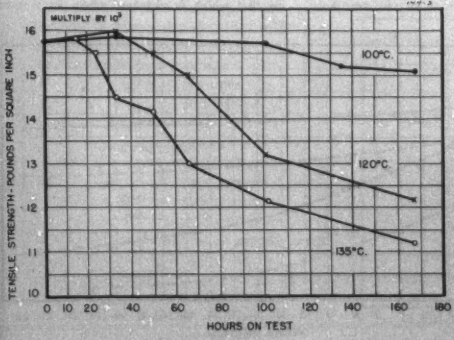


Figure 3. Showing the "stable period" of vacuum-dried, mineral-transformer-oil-treated, and oil-immersed 0.003-inch Manila paper when heated in contact with oxygen gas

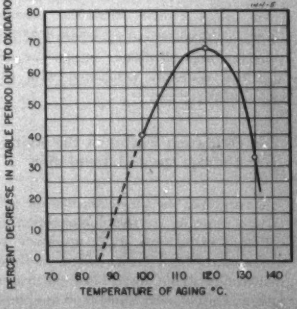


Figure 5. The effect of oxidation on the duration of the "stable period" for vacuum-dried oil-impregnated, and oil-immersed 0.003-inch Manila paper reaches its maximum at approximately 120 degrees centigrade

the oil-treated cellulose assumes increasing importance. As a result, the duration of the "stable period" rapidly decreases even though all oxidizing gases are eliminated by the use of nitrogen. This is also illustrated in figure 5.

The existence of a "stable period" is of importance in the application of cellulose insulation in oil-filled electrical apparatus. The prolongation of this period is the most important result obtained by the elimination of an oxidizing atmosphere in contact with the oil-immersed insulation. The beneficial results obtained by the use of nitrogen gas, however, are largely limited to temperatures between 100 degrees centigrade and 120 degrees centigrade. For lower temperatures, the oxidation effect is of negligible importance. For higher temperatures, the pyrochemical decomposition reaction

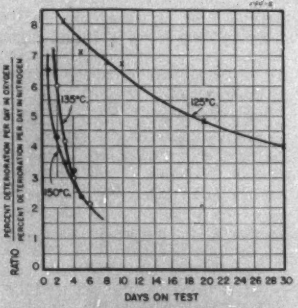


Figure 6. In the heat treatment of vacuum-dried but unimpregnated 0.003-inch Manila paper in sealed bombs under 250 pounds gas pressure, the deterioration in tensile strength is accelerated by the presence of oxygen

of the cellulose rapidly increases in importance and ultimately masks the advantages normally associated with the use of nitrogen gas.

The Oxidation Factor in the Aging of Unimpregnated Insulation

In studying the importance of the oxidation reaction in the deterioration of cellulose insulations, it is necessary to differentiate between its effect on those insulations which have been oil-treated and are tested under mineral oil and those insulations which are tested without oil impregnation and in direct contact with an oxidizing atmosphere. In order to illustrate more clearly the effects of oxidation in terms of tensile strength, it has

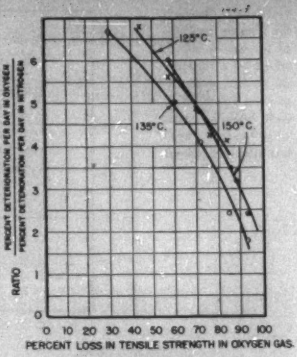

RATIO
PERCENT DETERIORATION PER DAY IN OXYGEN / PERCENT DETERIORATION PER DAY IN NITROGEN
125°C.
135°C.
150°C.
PERCENT LOSS IN TENSILE STRENGTH IN OXYGEN GAS

Figure 7. When vacuum-dried but unimpregnated 0.003-inch Manila paper is heated in sealed bombs under 250 pounds of gas pressure, the loss in tensile strength is accelerated by the presence of oxygen gas to approximately the same extent as the temperature is changed within the range from 125 degrees centigrade to 150 degrees centigrade

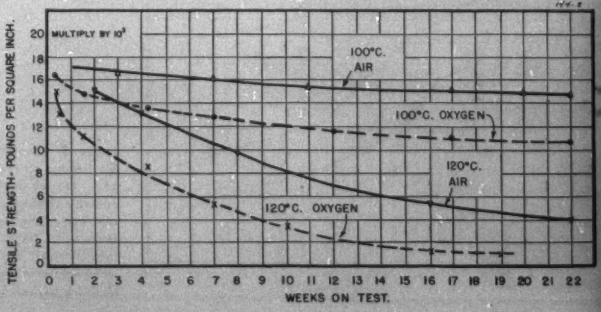
been found desirable to exaggerate the oxidation reaction by the use of oxygen gas in place of air. The effect on unimpregnated insulation is easily demonstrated. Figure 6 illustrates the importance of oxidation as a factor in the mechanical deterioration of dried but unimpregnated 0.003-inch Manila cable paper, aged at 125 degrees, 135 degrees, and 150 degrees centigrade in sealed bombs under 250 pounds of gas pressure. The results are expressed in terms of the accelerated rate of deterioration produced by the presence of oxygen gas as compared to similar aging in the presence of nitrogen. As the deterioration of the cellulose progresses, irrespective of the temperature of test, the accelerating effect of oxygen gas rapidly diminishes. During the initial state of the temperature exposure, however, the increased rate of aging due to the oxidation of the unimpregnated insulation reaches a high value.

The marked effect of the oxidation reaction during the initial stages of the high-temperature exposure of dried but unimpregnated cellulose results from the longer duration of the "stable period" when the insulation is in contact with a nonoxidizing atmosphere. When once the "stable period" in nitrogen gas has been passed, however, and the paper begins to deteriorate because of pyrochemical decomposition, the increased rate of deterioration in oxygen gas as compared to that observed in nitrogen rapidly decreases. The decrease is substantially independent of the temperature. This is illustrated in the data of figure 7 which correlate the accelerating effect of oxidation caused by the presence of oxygen gas with the degree of deterioration observed. It is important to note that with dried but unimpregnated Manila paper, even though the effect of oxidation decreases as the deterioration progresses, there is nevertheless a pronounced acceleration of deterioration throughout the whole mechanical life of the insulation.

The Oxidation Factor in the Aging of Oil-Impregnated Insulation

In order to evaluate the importance of oxidation in the deterioration of oil-treated and oil-immersed cellulose insulation, it has been found desirable, as in the study of the unimpregnated insulation, to exaggerate those factors which accelerate oxidation. For this purpose, pure

Figure 8. When vacuum-dried, oil-treated, and oil-immersed 0.003-inch Manila paper is aged in glass tubes sealed at atmospheric pressure, the presence of oxygen gas accelerates the loss in mechanical strength as compared to that which is obtained when air is used



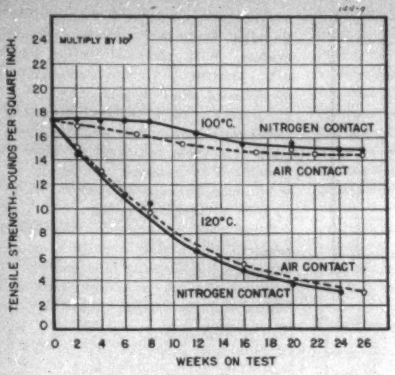


Figure 9. The loss of the tensile strength for vacuum-dried, oil-treated, and oil-immersed 0.003-inch Manila paper when aged in contact with nitrogen gas in glass tubes sealed at atmospheric pressure closely duplicates the deterioration observed when air is substituted for the nitrogen

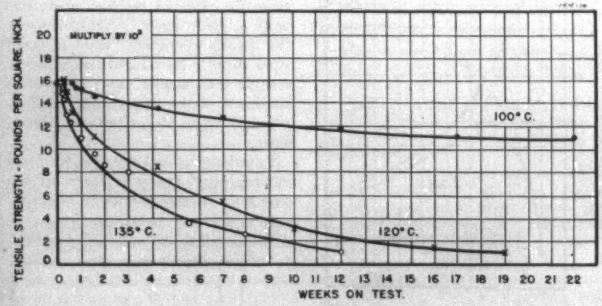


Figure 10. The loss in mechanical strength of vacuum-dried, oil-impregnated, and oil-immersed 0.003-inch Manila paper when heated in sealed tubes in contact with oxygen gas

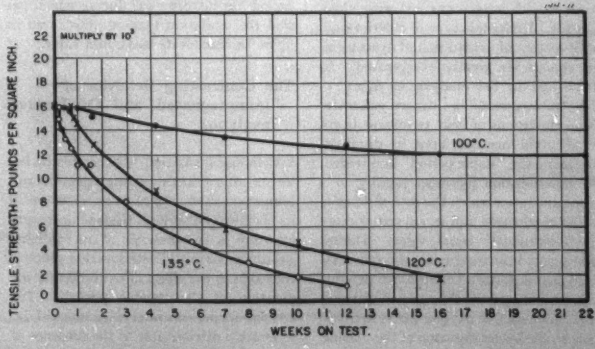
oxygen has been used in place of air. The oxygen gas has been applied both at atmospheric pressure and at 250 pounds per square inch in sealed bombs. Temperatures of test as high as 200 degrees centigrade have been investigated.

The results of accelerated tests in which the possibility of oxidation has been greatly exaggerated must be considered merely as the ultimate limit of oxidation. It must not be concluded from such tests that an equal degree of deterioration will be obtained for the same oil-treated and oil-immersed insulation in contact with the air which is normally present in commercial usage. A typical comparison of the aging of 0.003-inch Manila paper in air and in oxygen is illustrated in figure 8 for tests at 100 degrees and 120 degrees centigrade. The deterioration observed in the insulation aged in contact with air in figure 8 is substantially the same as that observed when the insulation is aged in contact with nitrogen under similar test conditions (figure 9).

Despite the difference in the rate of aging in oxygen and in air, the use of oxygen serves the practical laboratory purpose of bringing out the effects of oxidation under the most favorable, lower temperature conditions at which the effect of nonoxidizing chemical changes are reduced or eliminated. Figures 10 and 11 give detailed illustrations of the aging of 0.003 inch vacuum oil-treated and oil-immersed Manila cable paper sealed in glass tubes at atmospheric pressure, the surface of the oil being in contact with oxygen and with nitrogen gas.

One of the outstanding characteristics which distinguishes the aging of cellulose insulations in contact with oxygen gas from similar aging in contact with nitrogen is the shorter duration of the "stable period" when oxidation occurs. It is obvious from the data presented that any evaluation of the possible acceleration of aging due to oxidation will depend upon that stage of the heat treatment selected for the comparison. If an interval during the "stable period" is selected as the time of comparison, it will be concluded that oxidation is of serious import. If on the other hand, the point of comparison is taken after considerable mechanical deterioration has occurred, entirely different conclusions will be drawn. This is illustrated in figure 12, based on the data of figures 10 and 11. The acceleration of mechanical deterioration due to the presence of oxygen as compared to nitrogen gas is shown as a function of the duration of the aging exposure at 100 degrees centigrade, 120 degrees centigrade, and 135 degrees centigrade. At the lower temperature pronounced oxidation effects are observed during the initial stages of the test. At the end of about four days of aging, the deterioration in oxygen gas at 120 degrees centigrade is approximately 4½ times faster than in nitrogen. This results from the longer duration of the "stable period" in the absence of oxi-

Figure 11. The loss in mechanical strength of vacuum-dried, oil-impregnated, and oil-immersed 0.003-inch Manila paper when heated in sealed tubes in contact with nitrogen gas



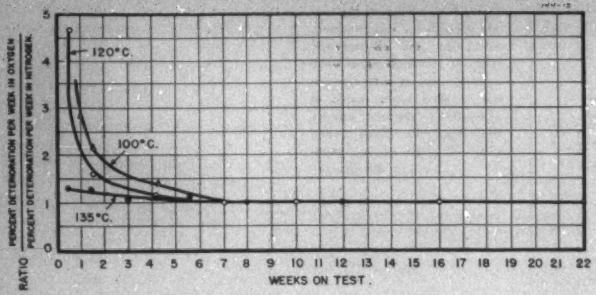

120°C.
100°C.
135°C.
RATIO PERCENT DETERIORATION PER WEEK IN OXYGEN / PERCENT DETERIORATION PER WEEK IN NITROGEN
WEEKS ON TEST

Figure 12. When vacuum-dried, oil-treated, and oil-immersed 0.003-inch Manila paper is heated in glass tubes sealed at atmospheric pressure, the oxidation factor assumes decreasing importance as the aging run progresses

dation effects. At the end of this "stable period" however, rapid changes in the oxidation ratio occur. Deterioration of the insulation in contact with nitrogen gas causes the oxidation ratio to fall rapidly. Within the limits of the available data, it is concluded that the rate of deterioration of the cellulose is progressively less affected by oxidation as the aging continues. When the deterioration has progressed to the extent that approximately 50 per cent of the original strength has been lost, the effects of the oxidation reaction are masked by the increasing importance of pyrochemical deterioration.

A further illustration showing the change from a condition of oxidation type of deterioration to a condition where the pyrochemical type predominates is illustrated in figure 13. In this study the dried, oil-impregnated, and oil-immersed 0.003-inch Manila paper insulation is heat treated at 200 degrees centigrade in contact with oxygen gas and with nitrogen gas. Under this type of deterioration both factors of oxidation and pyrochemical change are greatly exaggerated. As illustrated in the analysis of figure 13 the "stable period" in nitrogen gas under these conditions of heat treatment is approximately one-half hour in duration. Following the "stable period" in nitrogen, the deterioration increases rapidly to a maximum, after which the rate of deterioration in nitrogen and in oxygen appears of approximately equal value. During subsequent heat treatment, the only distinguishable feature between the deterioration resulting from the aging in nitrogen gas as compared to oxygen gas is attributable to the longer duration of the "stable

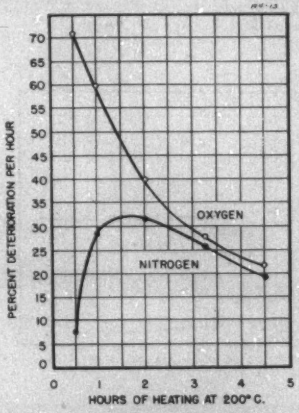


Figure 13. When vacuum-dried, oil-treated, and oil-immersed 0.003-inch Manila paper is aged at 200 degrees centigrade in glass tubes sealed at atmospheric pressure, the effects of oxidation, clearly evident in the initial stages of the heat treatment with oxygen are later masked by the presence of pyrochemical deterioration which occurs even in the presence of nitrogen gas

period" in nitrogen gas during which period the oxidation ratio as illustrated in figure 14 reaches its maximum value.

The Contrasting Behavior of Unimpregnated and Oil-Treated Insulation

Cellulose insulation whether tested before or after mineral oil impregnation and immersion shows the same peculiarities in its chemical behavior. High-temperature exposure in the presence of an oxidizing gas causes an initial deterioration which is traceable to the effect of oxidation on the duration of the "stable period." Examined during this interval, a marked deterioration attributable to the presence of oxygen gas as compared to the corresponding change in nitrogen gas is clearly evident. With continued heating, however, pyrochemical decomposition changes are initiated which become of increasing importance as the insulation is subjected to exhaustive treatment. It is the interrelation of these two types of chemical change and their modification as a result of oil impregnation and immersion which compels special consideration.

When dried but unimpregnated cellulose insulation is aged in an oxidizing atmosphere, the fibers are in intimate contact with what may be considered an unlimited supply of oxygen. Aged after oil impregnation and oil immersion, the amount of immediately available oxygen is limited to that supplied from oil solution. The result is that at temperatures where the oxidation reaction would normally be predominant, as for example at 120 degrees centigrade, unimpregnated paper shows a more rapid loss in tensile strength than similar paper oil impregnated and oil immersed. This is illustrated in figure 15 for tests on Manila paper.

A similar relation holds true when the cellulose deterioration is caused by the application of temperature in the range

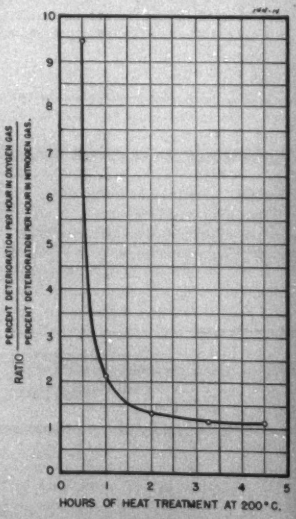

RATIO PERCENT DETERIORATION PER HOUR IN OXYGEN GAS / PERCENT DETERIORATION PER HOUR IN NITROGEN GAS.
HOURS OF HEAT TREATMENT AT 200°C.

Figure 14. Showing the marked decrease in the oxidation factor after the end of the "stable period" for the aging of vacuum-dried, oil-treated, and oil-immersed 0.003-inch Manila paper in sealed glass tubes at 200 degrees centigrade

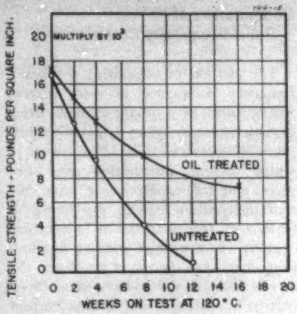


Figure 15. The mechanical aging of vacuum-dried 0.003-inch Manila paper is decreased as the result of impregnation and immersion in mineral transformer oil

The heat treatment in this illustration is carried out in glass tubes sealed at atmospheric pressure, the gas present being dried air

where pyrochemical decomposition is rapid and severe even in the presence of nitrogen. This is not unexpected in view of the fact that, as already described in a previous paragraph, the "dormant" period is increased as a result of oil impregnation and immersion. The longer duration of the dormant period for oil-treated and oil-immersed insulation in the absence of oxidation is undoubtedly related to the slower rate of acid formation in paper when exposed to high temperatures after oil treatment.[1] The result is that at a temperature of 135 degrees centigrade, dried but unimpregnated Manila paper deteriorates in tensile strength at a more rapid rate than does similar paper after oil impregnation and oil immersion. This is illustrated in figure 16.

In comparing the stability of cellulose insulation before and after oil impregnation the conditions of the comparison must be carefully stated. Dried but unimpregnated cellulose may be expected to deteriorate more rapidly than the same material after oil impregnation when the conditions of the temperature treatment are such that severe oxidation or pyrochemical reactions are possible. Heated under conditions such that oxidation and pyrochemical changes are of minor importance, the mechanical deterioration of the cellulose insulation is substantially unaffected by the presence of the impregnating mineral oil in which the material may be immersed.

Summary

1. Cellulose insulation will deteriorate in mechanical strength at a rate which increases with the increasing temperature of exposure. Deterioration will occur in the absence of an oxidizing atmosphere.

2. The rate of cellulose deterioration at a fixed temperature varies as the heat treatment is continued.

3. The mechanical deterioration of cellulose insulation at elevated temperature is the result of oxidation and pyrochemical decomposition.

4. When heated, cellulose passes through a "stable period" during which the mechanical properties are maintained. The presence of oxygen is chiefly effective in reducing the duration of this "stable period."

5. The single effect of oxidation is restricted to the initial periods of treatment at temperatures lower than approximately 120 degrees centigrade. At higher temperatures, pyrochemical decomposition occurs. Even in the most favored temperature range, the effect of cellulose oxidation merges into the effects produced by pyrochemical decomposition as the deterioration progresses.

6. Heated under conditions which favor oxidation or pyrochemical change, the unimpregnated cellulose insulation deteriorates more rapidly than the same insulation after oil treatment and immersion.

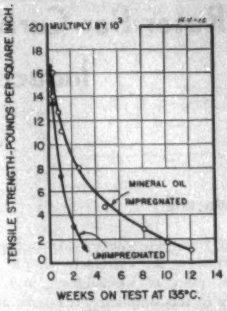


Figure 16. When heated at 135 degrees centigrade in sealed glass containers in contact with nitrogen gas, the rate of loss in tensile strength of dried 0.003-inch Manila paper is substantially decreased as a result of impregnation and immersion in mineral transformer oil

7. The effect of oxidation is accelerated when pure oxygen gas is in contact with the insulation. No substantial difference in the rate of mechanical deterioration is observed when the oil-treated and oil-immersed insulation is aged in contact with nitrogen gas as compared to aging in contact with air.

Bibliography

1. Pyrochemical Behavior of Cellulose Insulation, **F. M. Clark.** AIEE Transactions, volume 54, 1935, pages 1088–94.

2. Correlation of the Chemical and Electrical Changes Observed During the Oxidation of Mineral Insulating Oil, **F. M. Clark.** ASTM Preprint number 99, 1940.

3. Loading Transformers by Temperature, **V. M. Montsinger.** AIEE Transactions, volume 49, 1940, pages 776–90.

4. Temperature Aging Characteristics of Class A Insulation, **J. J. Smith** and **J. A. Scott.** AIEE Transactions, volume 58, 1939 (September section), pages 435–42.

5. Temperature Limits Set by Oil and Cellulose Insulation, **C. F. Hill.** AIEE Transactions, volume 58, 1939 (September section), pages 484–7.

Rotor-Bar Currents in Squirrel-Cage Induction Motors

J. S. GAULT
MEMBER AIEE

Introduction

THE rotor of a squirrel-cage induction motor is an extremely simple and rugged piece of mechanism; and due largely to this simplicity, it resists accurate analysis of its behavior by ordinary testing technique. Its design has been perfected by cut and try methods, making assumptions with respect to rotor current to simplify the theory; but the actual current in the bars has remained a mystery. The purposes of this paper are: first, to present oscillograms of rotor-bar currents; second, to extend the theory of induction motors to include the computation of rotor-bar currents; and third, to show the effect of the rotor current harmonics upon the efficiency of the motor.

Rotor-Bar Currents

The current in the rotor bars of a squirrel-cage induction motor is a composite wave of complicated form in which, however, three main components are prominent. In addition to the slip-frequency component which increases directly with load, there is a component due to nonuniform reluctance, the tooth-frequency component. The magnitude of this component depends primarily upon flux density but also increases with load; its frequency depends upon the number of stator teeth and the speed. The tooth-frequency component is very pronounced in a machine with open slots and is considerably reduced by using closed slots or nearly closed slots. The third main component of rotor frequency is caused by the nonsinusoidal distribution of stator current, and will be designated the band-frequency component.

A polyphase stator winding excited by current of sinusoidal wave shape gives a stator magnetomotive force with nonsinusoidal distribution. This would produce a rotating field with nonsinusoidal shape, although the flux density at every point along the air gap would vary sinusoidally in time to give a sinusoidal generated voltage in the stator. In a wound-rotor motor, space harmonics in the stator flux wave produce corresponding harmonics in the rotor generated voltage; but in a squirrel-cage motor, irregularities in the flux wave are practically eliminated by currents induced in the short-circuited rotor conductors. The rotor current distribution is such that the total current distribution, rotor plus stator, is sinusoidal. This hypothesis is given in Professor Bailey's book,[1] and is substantiated by analysis of the rotor current oscillograms included in this paper.

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Acknowledgments: For materials and aid in this investigation, a grant was obtained from the department of engineering research at the University of Michigan. Professor Lewis N. Holland, electrical engineering department, designed the amplifier and power supply, and supervised its construction and testing. Acknowledgement is also made to Professor Benjamin F. Bailey, chairman of the department of electrical engineering, for inspiration and guidance during the investigation and for valuable help in preparation of this paper.

1. For all numbered references, see list at end of paper.

Computation of Band-Frequency Component

The method of computing the band-frequency component of rotor current will be shown by a specific example, using a three-phase winding with two-thirds pitch, 12 slots per pole. The curves of stator current distribution over two poles, and the corresponding rotor current distribution curves, are shown in figure 1, at time intervals of 15 electrical degrees. In the stator winding distribution diagram at the top of the figure, the arrows indicate the positive direction of current in each coil side, not the current distribution at a particular time. The cyclic maximum value of stator current per coil side (turns per coil times maximum stator current per conductor) is denoted by I_s. At the time ($\theta=0$ degrees) the instantaneous values of currents, indicated in the vector diagram at the left, are:

Phase $A=0$
Phase $B=-0.866I_s$
Phase $C=0.866I_s$

Using these values with the winding distribution diagram, the curve of stator current distribution, S, is obtained for time ($\theta=0$). The rotor current distribution curve, R, is drawn so that the total current curve, T, is the sinusoidal equiva-

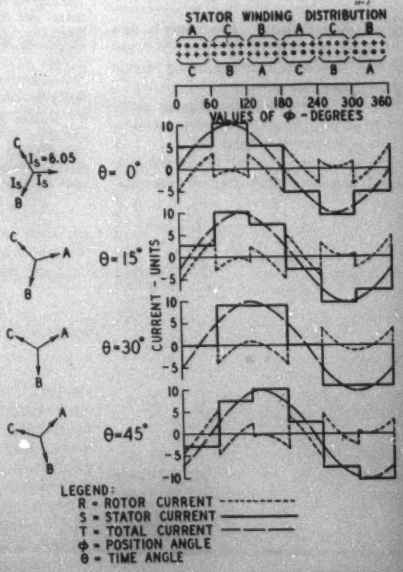


Figure 1. No-load current distribution curves of three-phase winding with 2/3 pitch

lent of the stator current curve, that is the fundamental component of the curve S. The amplitude, T_m, may be obtained by use of the formula for the co-

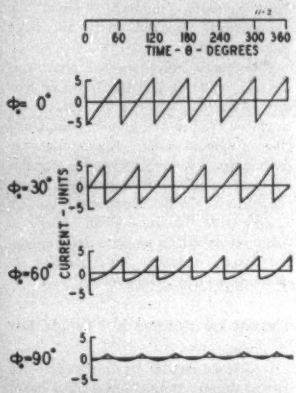


Figure 2. Rotor-bar current at zero slip for three-phase winding with 2/3 pitch

efficient of the fundamental term of the Fourier series:

$$T_m = \frac{2}{\pi}\int_0^{\pi} S \sin\phi d\phi \qquad (1)$$

For the time ($\theta = 0$) the values of stator current shown give:

$$T_m = \frac{2}{\pi}\left[\int_0^{\pi/3} 0.866 I_s \sin\phi d\phi + \int_{\pi/3}^{2\pi/3} 1.732 I_s \sin\phi d\phi + \int_{2\pi/3}^{\pi} 0.866 I_s \sin\phi d\phi\right]$$

$$= \frac{3\sqrt{3}}{\pi} I_s \qquad (2)$$

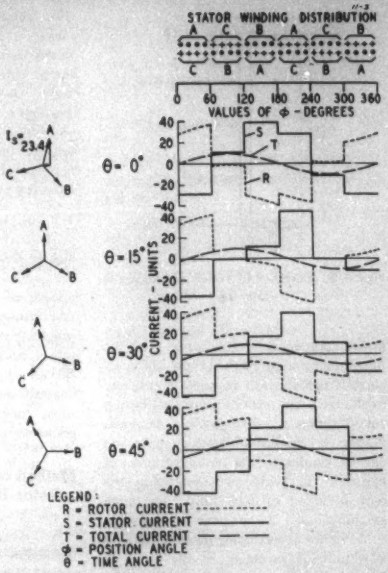
and at any other time, the same value will be found for T_m. In figure 1, a value of I_s is chosen arbitrarily to make T_m = ten units, so:

$$I_s = \frac{10\pi}{3\sqrt{3}} = 6.05 \text{ units} \qquad (3)$$

and all the curves are drawn to this scale.

The rotor current distribution curves may be used to obtain the time curve of current in a particular bar by following a point on the rotor as it turns with the field. Due to discontinuities in the distribution curves, the time curves of rotor current cannot be obtained by Fourier analysis; however by using the values on the curves in figure 1, the curves of figure 2 may be obtained. The curve ($\phi_0 = 0$)

Figure 3. Full-load current distribution curves of three-phase winding with 2/3 pitch



shows current in the rotor bar which is in position ($\phi = 0$) at time ($\theta = 0$), so the value 5.24 units is taken at the point ($\phi = 0$) on the curve for time ($\theta = 0$) in figure 1. At time ($\theta = 15$ degrees) the rotor has moved 15 degrees to the right, so the value of rotor current is taken from the ($\theta = 15$ degrees) curve at point ($\phi = 15$ degrees). The values of rotor current in this bar at $\theta = 30$ degrees and 45 degrees are read similarly from the corresponding curves at the 30-degree and 45-degree points respectively. At ($\theta = 60$ degrees) the distribution curves are like the ($\theta = 0$) curves and the rotor current wave repeats, so the rotor-bar current in this case is a 360-cycle wave of nearly triangular wave shape. The curve ($\phi_0 = 30$ degrees) in figure 2 is obtained similarly; the first point is taken from the ($\theta = 0$) curve at ($\phi = 30$ degrees), etc. For different bar positions, the magnitude of this band-frequency component changes as well as the wave shape with a maximum value for the position ($\phi_0 = 0$):

$$R_b = 6.05 \sin 60° = 5.24 \text{ units} \qquad (4)$$

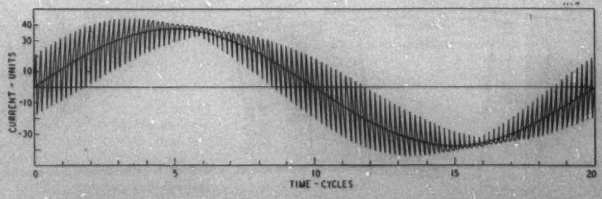
and only 0.67 unit for the bar in the ($\phi_0 = 90$ degrees) position.

The curves of figure 2 represent rotor-bar currents in a machine running at synchronous speed. At no load with a small amount of slip, these curves show some of the phases through which the rotor current passes slowly as the bar changes its position with reference to the revolving field.

Effect of Load Upon Rotor Current

When the motor is loaded, the stator current is increased by the addition of a

Figure 4. Rotor-bar current at full-load with 5 per cent slip, for three-phase winding with 2/3 pitch



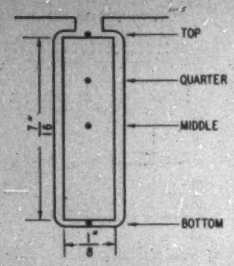


Figure 5. Positions of search conductors in rotor bar

power component in quadrature with the magnetizing component. Since the total current distribution remains practically unchanged, the rotor current distribution curve shows a corresponding increase. Figure 3 shows full-load distribution curves, similar to the no-load curves of figure 1. The value of magnetizing current is taken as 6.05 units, the same as the no-load value given in equation 3. For the power component a value of 22.6 units is assumed, so the value of I_s used in drawing the curves of figure 3 is:

$$I_s = 6.05 + j22.6 = 23.4 \text{ units (at 75 degrees)} \quad (5)$$

The total current, T_m, equals ten units as before.

The curve of rotor-bar current in figure 4 is obtained from these distribution curves by following a point on the rotor, using a slip of five per cent which corresponds to full load. The rotor current now shows a slip-frequency component with amplitude, R_s, proportional to the power component of stator current:

$$R_s = 22.6 \times \frac{3\sqrt{3}}{\pi} = 37.35 \text{ units} \quad (6)$$

The band-frequency component increases with the stator current, so the maximum amplitude:

$$R_b = \frac{23.4}{6.05} \times 5.24 = 20.3 \text{ units} \quad (7)$$

The frequency of this component also changes. At synchronous speed each 60-degree band of the stator winding produces one cycle of the band-frequency wave. As the speed decreases, the band-frequency drops; and for each cycle of slip frequency, the band-frequency component passes through all its phases corresponding to a complete cycle. The band frequency for a value of slip, s, is:

$$f_b = (1-s)6f + sf = (6-5s)f \quad (8)$$

and at five per cent slip, this frequency is 345 cycles. This band-frequency component is superposed on the sinusoidal (slip-frequency) component; and it passes progressively through the various phases shown in figure 2. In these computed curves the tooth-ripple frequency is omitted, and this should be kept in mind when comparing them with the oscillograms shown later.

Method of Measuring Rotor-Bar Current

In February 1937, an article by Narbutovskih[3] showed a method of obtaining rotor-bar current curves by placing search conductors in the rotor bar. The search conductor is an insulated wire running through the rotor bar under observation, and connected to it at the back end. The front end of the test conductor and the front end of the rotor bar are connected through sliding contacts to the first stage of an amplifier, so no current is drawn from this test circuit. The voltage between the leads is equal to the instantaneous value of iR drop in the bar material adjacent to the test conductor and therefore is proportional to the current density.

The article is most interesting because these oscillograms constitute the first published record of actual rotor-bar currents which has come to the writer's attention. The tests were run on an early type of machine with nearly square rotor bars, and an open slot stator which produced a large tooth ripple in the rotor current. From a study of the oscillograms, it is not apparent that the amplifier used had a frequency range low enough to show slip frequency. The band-frequency component is discernible but is nearly covered up by the large tooth-frequency component.

Preliminary tests showed that this method would permit the study of harmonics in the rotor-bar current, which would be even more interesting in a machine of modern design. An amplifier was constructed with a power stage suitable for direct connection to a magnetic oscillograph; with maximum voltage amplification about 50,000. Used in combination with a power supply of special design, it has a flat-frequency response from 1 to 2,000 cycles.

Current Distribution in a Single Bar

As pointed out by Narbutovskih,[3] the current density throughout a rotor bar is far from uniform, particularly for high-frequency components, due to rotor leakage flux. A search conductor in the rotor bar does not, therefore, measure the current in the bar, but rather the current density adjacent to the test conductor. In a narrow rectangular bar the current density across the bar will be nearly uniform, except for very high-frequency components, but will vary with the depth in the bar. For the tests reported in this paper, four search conductors were used, placed as shown in figure 5. Specifications on the machine tested were:

Rating: 220 volt, 3 phase, 60 cycle, 5 horsepower, 1,800 rpm

Stator: 48 coils, 22 turns No. 15, throw 1–9, connected parallel-wye

Rotor: 45 copper bars, $^1/_8$ by $^7/_{16}$ inch, length 2.38 inches copper end rings, $^1/_4$ by $^{29}/_{32}$ inch, mean radius 2.89 inches

The dimensions of rotor slots and teeth, air gap, and stator slot openings are shown in figure 6, all dimensions in inches.

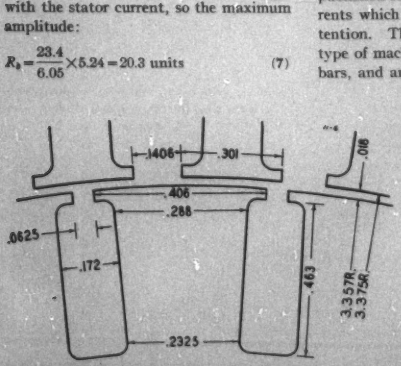


Figure 6 (left). Rotor slot and tooth dimensions

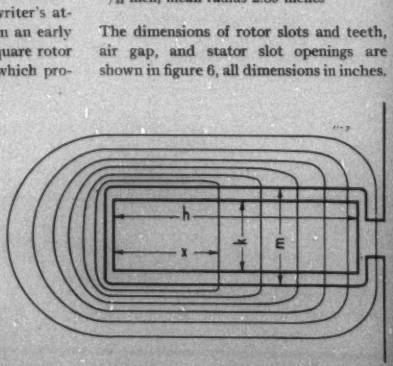


Figure 7. Rotor-bar leakage flux pattern

Figure 7 shows a bar of thickness, k, and depth, h, in a slot of width, m, with all dimensions in inches. Certain simplifying assumptions are made concerning the leakage flux pattern which are quite valid for a narrow rectangular bar nearly filling the slot. Due to the higher reactance of the lower part of the bar, the current density is highest at the top of the bar and diminishes to a minimum at the bottom. Also the current in lower layers is lagging in phase. Both of these effects are most noticeable at high frequency, are relatively small at 60 cycles, and are practically negligible at slip frequency. The current distribution for a particular frequency is given by the formulas:

$$U_x = A\sqrt{2\cosh(2ax) + 2\cos(2ax)} \qquad (9)$$

$$\tan \psi_x = \tanh(ax) + \tan(ax) \qquad (10)$$

where U_x is the cyclic maximum current

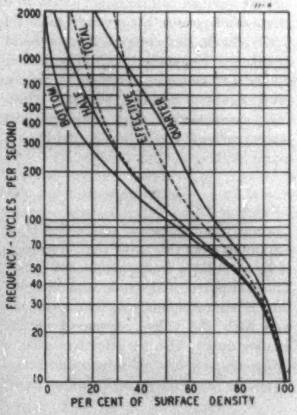


Figure 8. Current density at different levels in per cent of surface density

density at a distance, x, from the bottom of the bar.

$$A = \frac{U_h}{\sqrt{2\cosh(2ah) + 2\cos(2ah)}} \qquad (11)$$

where U_h = current density at the top of the bar.

$$a = \sqrt{\frac{1.003kf}{\rho m 10^7}} \qquad (12)$$

ρ = resistivity in ohms per inch cube

f = frequency in cycles per second

ψ_x = phase angle of current at point x with respect to that at the bottom of the bar

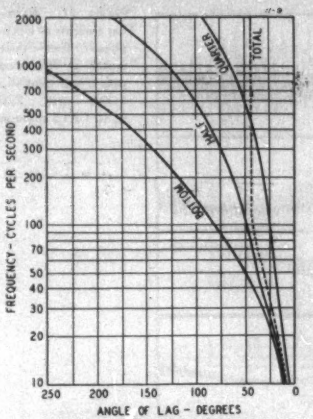


Figure 9. Angle of lag at different levels referred to current at top of bar

In accordance with these formulas, the curves of figure 8 are computed to show the current density at the quarter, middle, and bottom of the bar used, in per cent of the value at the top, for the range of frequencies encountered. Figure 9 shows the angle of lag of the current at the same levels with respect to that at the top of the bar. For the 360-cycle band-frequency component discussed previously, for example, the distribution and phase, taken from these curves, are shown in table I. The current density falls off rapidly with the depth, also the phase shift is large, therefore the average density is only 26 per cent of the density at the surface. The formula for computing this average is:

$$U_{av} = \frac{A}{ah}\sqrt{\cosh(2ah) - \cos(2ah)} \qquad (13)$$

and the phase angle with respect to the current at the bottom of the bar is ψ_{av}, where:

$$\tan \psi_{av} = \frac{\tan(ah) - \tanh(ah)}{\tan(ah) + \tanh(ah)} \qquad (14)$$

It should be noted that the formula is developed in terms of "amperes per bar", that is, the density in amperes per square inch multiplied by the bar area; so the average current density is numerically equal to the total bar current. The formula for effective or rms density, in the same units, is:

$$U_{eff} = A\sqrt{\frac{\sinh(2ah) + \sin(2ah)}{ah}} \qquad (15)$$

These formulas are developed on the basis of sinusoidal wave shape. The band-frequency wave is very nearly triangular so the current density drops a little faster than for a sine wave of the same frequency, due to the higher frequency components of the wave. The wave shape also improves, and becomes nearly sinusoidal near the bottom of the bar. Nevertheless, the curves of figure 8 give a reasonably correct picture of current distribution, especially if a small correction is made for wave shape, and they agree closely with the results obtained by measurements on oscillograms.

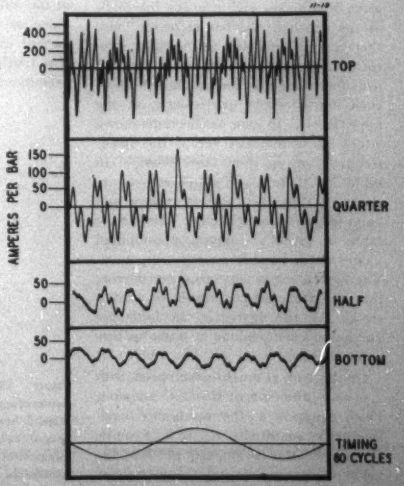


Figure 10. Rotor-bar currents of three-phase four-pole motor at synchronous speed, 1,800 rpm, 220 volts, 3.31 amperes

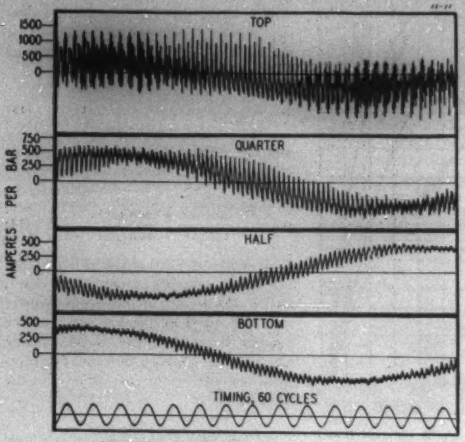


Figure 11. Rotor-bar currents of three-phase four-pole motor at full load with 5 per cent slip 1,710 rpm, 220 volts, 13.15 amperes

Rotor Current Oscillograms

Figure 10 shows rotor current oscillograms for the three-phase motor running at synchronous speed, 1,800 rpm, together with a 60-cycle timing wave. The curves at the different levels in the bar were not actually taken simultaneously, since only one amplifier was used. By means of a stroboscope, the curves were all taken at the same point in the band-frequency cycle; then the waves were lined up on the sheet by means of their separate timing waves, of which only one is shown. By noting the current scales, it is seen how the band-frequency wave diminishes and changes its shape as the depth in the bar increases; also there is a gradual shift to the right, indicating a greater angle of lag. These effects are hidden by the prominent 1,440-cycle tooth ripple, particularly at the upper levels. In some oscillograms shown later, for a different setup, the band-frequency waves show more clearly. In table II, these oscillograph curves are analyzed into the tooth-frequency and band-frequency components. Also in the table is given a column of computed values of the band-frequency component. The agreement is very good considering that the wave shape introduces a little error. All the figures in the table are maximum cyclic values in terms of amperes per bar.

On this test, at synchronous speed, with 220 volts, the current was 3.31 amperes. From equation 4, the maximum band-frequency amplitude, R_b, is 5.24 units. To convert this to amperes per bar, the value of stator maximum amperes per coil side is determined and this is multiplied by the ratio of stator to rotor slots. By equation 3, this is equal to 6.05 units. So:

$$6.05 \text{ units} = \frac{3.31\sqrt{2}}{2} \times 22 \times \frac{48}{45} \text{ amperes}$$

or

$$1 \text{ unit} = 9.09 \text{ amperes per bar} \qquad (16)$$

and

$$R_b = 5.24 \times 9.09 = 47.5 \text{ amperes per bar} \qquad (17)$$

This value appears in table II for "total" current (or average current density). The computed values of current density at the different levels and the "effective" value are figured from this value of total current using the percentages in table I. The tooth-frequency component is more prominent in the top layer, but falls off rapidly. Its effective value is rather hard to determine, but will undoubtedly be lower than that of the band-frequency component in this case.

In figure 11, are shown oscillograms taken under load with readings as follows:

Input—220 volts, 13.15 amperes, 4,570 watts
Output—5.03 horsepower, 1,710 rpm

No attempt has been made to line up this series of oscillograms with the single 60-cycle timing wave shown, and this is included merely to give the time scale which is the same for all curves. A little over one-half cycle of the three-cycle slip-frequency wave is shown at all four levels. As before, the tooth-frequency wave masks the band-frequency wave at the top of the bar. But at the quarter level, and especially at the middle of the bar, the tooth ripple is small and the band-frequency wave is quite prominent; also the similarity between these curves and the computed wave of figure 4 is very marked. The cyclic maximum values of the various components, scaled from these oscillograms, are given in table III.

To check the computation of band-frequency components, from equations 16 and 17 a stator current of 3.31 amperes gives $R_b = 47.5$ amperes per bar. Since this component varies directly with stator current, the value for the "total" under load is:

$$R_b = 47.5 \times \frac{13.15}{3.31} = 189 \text{ amperes} \qquad (18)$$

The maximum values at various levels are computed from this using the percentages of figure 8 for a frequency of 345 cycles. The computed magnitude and distribution of band-frequency current agree very well with the values measured on the oscillograms. Also the effective value of this component is of the same order of magnitude as the slip-frequency component.

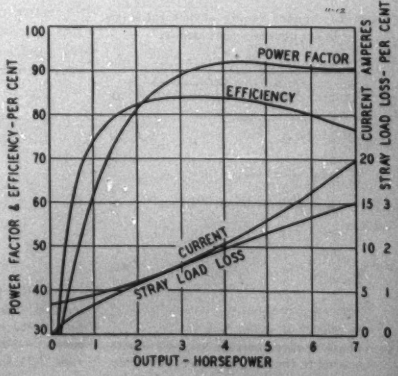


Figure 12. Load-test curves of squirrel-cage motor rated 5 horsepower, 1,800 rpm, three-phase 220 volts. Temperature 55 degrees centigrade

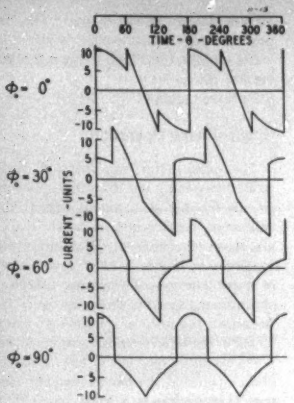


Figure 13. Rotor-bar current at zero slip for single-phase winding with 2/3 pitch

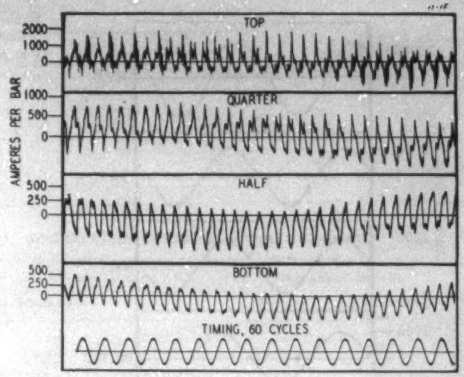


Figure 15. Rotor-bar currents of single-phase four-pole motor with 3.6 per cent slip

The slip frequency is only three cycles, so the value of this component at various levels should be the same as the total. This fact is clearly shown in the oscillograms, although the magnitude does not check so well. The slip-frequency component of rotor current is in space phase with the total magnetomotive-force wave, and is computed from the power component of stator current. The maximum value of this is approximately:

$$\sqrt{2}\times\sqrt{13.15^2-3.31^2}=12.72\sqrt{2}$$
$$=18 \text{ amperes} \quad (19)$$

The corresponding rotor-bar current, by equations 1 and 2, is:

$$R_s=\frac{3\sqrt{3}}{\pi}\times\frac{18\times22}{2}\times\frac{48}{45}=350 \text{ amperes} \quad (20)$$

As a further check upon the magnitude of the slip-frequency component, the slip-frequency loss was computed, also the total resistance per bar. The stator resistance between terminals was 1.139 ohms at 55 degrees centigrade, so the stator copper loss was 295 watts. The fixed loss was 220 watts. Therefore:

$$\text{Rotor input}=4{,}570-295-220=4{,}055 \text{ watts}$$

$$\text{Slip-frequency loss}=\frac{90\times4{,}055}{1{,}800}=203 \text{ watts} \quad (21)$$

The total rotor resistance per bar at 55 degrees centigrade is:

$$r=69\times10^{-6} \text{ ohms} \quad (22)$$

The amplitude of the slip-frequency component of current, then, computed from the value of loss shown in equation 21 is:

$$R_s=2\times\frac{203\times10^6}{45\times69}=359 \text{ amperes} \quad (23)$$

and this result checks very closely with the value shown in equation 20, but is 13 per cent less than the value scaled from the oscillograms, as shown in table III. This may indicate an error of approximately 15 per cent in the computed scale of the oscillograms, in spite of the care taken to obtain an accurate calibration.

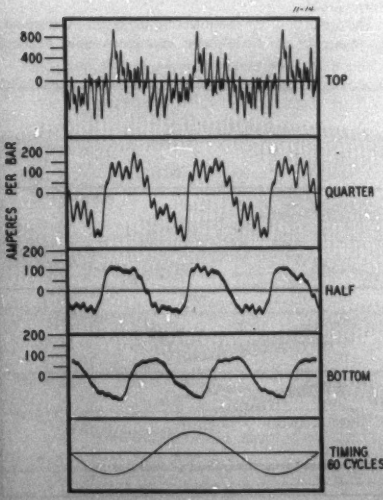


Figure 14. Rotor-bar currents of single-phase four-pole motor at synchronous speed, 1,800 rpm, 220 volts, 5.13 amperes

Effect Upon Motor Efficiency, Stray Loss

The total loss determined by the conventional method of losses is:

$$295+220+203=718 \text{ watts} \quad (24)$$

But the total loss determined by a careful dynamometer test is:

$$4{,}570-3{,}750=820 \text{ watts} \quad (25)$$

The stray loss at this load therefore is:

$$820-718=102 \text{ watts} \quad (26)$$

which is over two per cent. Performance curves for this motor are shown in figure 12, including a curve of stray loss in per cent of input. The shape of this curve is in substantial agreement with other published material.

Several writers on the subject of stray-load loss in induction motors agree that the loss is largely due to high-frequency flux pulsations in the stator teeth, plus a relatively small tooth-frequency eddy-

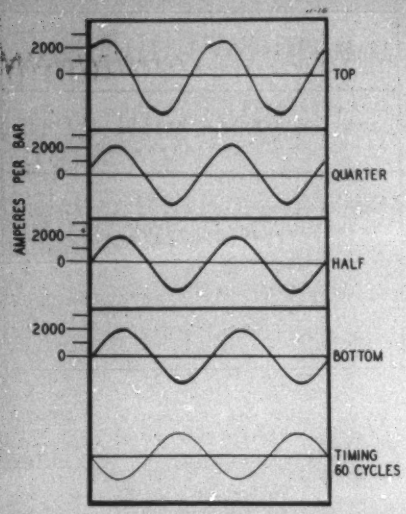


Figure 16. Rotor-bar currents of single-phase four-pole motor with rotor locked, 220 volts, 47.6 amperes

current loss in the rotor bars. In the tests reported herewith, the tooth-frequency eddy-current loss was found to increase with load. The lower frequency band-frequency eddy-current loss was found to be of even greater importance. At full load, this component (see figures 4 and 11) has a frequency of 345 cycles, and its amplitude rises and falls with a beat frequency of $2fs = 6$ per second. The rms value of this component per bar is computed to be:

$$I_b = \frac{U_{eff}}{2.38} = \frac{304}{2.38} = 128 \text{ amperes} \qquad (27)$$

Table I. Current Distribution and Phase for 360-Cycle Component

Level	Current Density (Per Cent)	Angle of Lag (Degrees)
Top	100	0
Quarter	50.1	39.1
Middle	24.2	79.3
Bottom	13.4	135.0
Average (total)	26.0	45.3
Effective	42.6	

Table II. Rotor-Bar Current Distribution in Figure 10

Level	Tooth-Frequency 1,440 Cycles	Band-Frequency = 360	
		Measured	Computed
Top	350	187	183
Quarter	33	55	91
Middle	10	30.5	44
Bottom	3	20	24.5
Total			47.5
Effective			78

Due to the distribution of this component in the end rings, the loss there is very small, and the resistance per bar may be taken as 34×10^{-6} ohms instead of the value given in equation 22. The rotor loss produced by this component therefore is:

$$W_b = 45 \times (128)^2 \times 34 \times 10^{-6} = 25 \text{ watts} \qquad (28)$$

This is about a quarter of the stray load loss.

In table III is shown a value of 225 amperes for the peak rms value of the tooth-frequency component. This was computed from the curve of measured current density values shown. The loss produced by this component is about 15 watts, so the total high-frequency rotor current loss is 40 watts, which is nearly one per cent of input.

Single-Phase Operation

The same motor was operated single phase by opening one line after it was up to speed. At synchronous speed the computed band-frequency wave shapes are shown in figure 13; the underlying frequency of course is 120 cycles. A set of rotor current oscillograms taken at synchronous speed is shown in figure 14. As before the full-load pictures of figure 15 show the band-frequency wave superposed on the power current, but for single-phase operation the band-frequency current (118 cycles) is a little larger than the slip-frequency current (2.2 cycles).

A locked test was also run on this motor connected single phase, and oscillograms are shown in figure 16. At standstill, all frequency components reduce to 60 cycles, giving a sine wave of current in the rotor bars. The shift in phase is shown by the drift to the right at the lower levels. Values of current density and phase angle with respect to the current at the top are shown in table IV; measured values taken from the film are compared with computed values. The check on phase angle is quite close. There is a satisfactory qualitative check on amplitude also, but the measured values seem to be too high, as noted previously in table III.

Consequent-Pole Winding

By reconnecting the coils of this motor, a three-phase consequent-pole winding

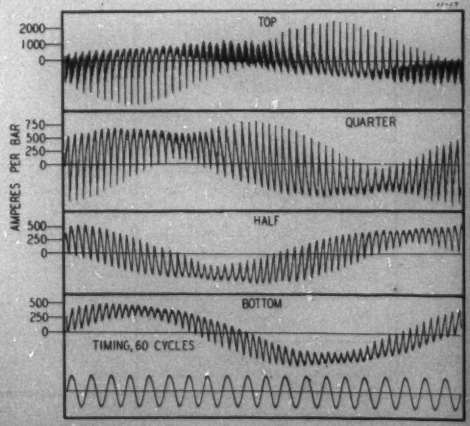


Figure 17. Rotor-bar currents of three-phase four-pole motor, consequent-pole connection 1,710 rpm, 190 volts, 14.4 amperes

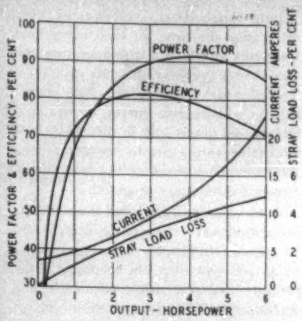


Figure 18. Load-test curves of three-phase four-pole motor, consequent-pole connection, 190 volts. Temperature 55 degrees centigrade

Table III. Rotor-Bar Current Distribution in Figure 11

Level	Tooth-Frequency 1,368 Cycles	Band-Frequency = 345		Slip-Frequency = 3	
		Measured	Computed	Measured	Computed
Top	930	873	707	417	350
Quarter	61	295	337	418	350
Middle	25	137	177	405	350
Bottom	19	86	102	415	350
Total			189	414	350
Effective	225	306	304	414	350

Table IV. Rotor-Bar Current Distribution and Phase in Figure 16

Level	Amperes Per Bar		Phase Angle—Degrees	
	Measured	Computed	Measured	Computed
Top	2,628	2,168	0	0
Quarter	2,153	1,756	28.1	20.4
Middle	1,943	1,578	39.7	40.7
Bottom	1,870	1,530	57.3	57.9
Total		1,578		35
Effective		1,673		

was produced with eight coils per phase group for four-pole speed, that is using a phase band width of 120 degrees instead of 60 degrees and only two polar groups per phase. Upon analysis this gave a band-frequency wave similar to that shown in figure 2, but of half its frequency (180 cycles at synchronous speed) and approximately twice its amplitude. This is noted in the load oscillograms of figure 17. The load-test curves of figure 18 show decreased efficiency, particularly at heavier loads, and a considerable increase in stray-load loss, due almost entirely to the larger band-frequency current in the rotor bars. The test was run on 190 volts to get the same flux density in the motor.

Eight-Pole Operation

The stator winding was reconnected for three-phase eight-pole operation. Using the same coils as before, the coil pitch is four-thirds, which produces a band-frequency wave like that in figure 2; so the load oscillograms shown in figure 19 are quite similar to those in figure 11 except that the tooth ripple is almost entirely gone.

Conclusions

High-frequency components in the rotor-bar current may contribute a considerable portion of the stray-load loss in a squirrel-cage motor. By proper slot design, the tooth-frequency component may be controlled. The band-frequency component, however, depends upon the winding, and may be decreased by coordinating pitch and number of phases. If a pitch of five-sixths instead of two-thirds had been used with the three-phase four-pole winding, the band-frequency wave would be as shown in figure 20 instead of that shown in figure 2. An analysis of this wave shows a band-frequency current loss of about one-third as much.

References

1. The Induction Motor (a book), **Benj. F. Bailey.** McGraw-Hill Book Co., pages 102–4, 195–8.

2. Tooth-Frequency Eddy-Current Loss, **Paul Narbutovskih.** AIEE Transactions, volume 56, 1937 (February section), page 253.

3. Measurement of Stray Load Loss in Polyphase Induction Motors, **C. J. Koch.** AIEE Transactions, volume 51, 1932, page 756.

4. Zusätzliche Verluste in Kleinen Drehstrommotoren, **Rogowski** and **Vieweg.** *Archiv für Elektrotechnik*, volume 14, 1925, page 574.

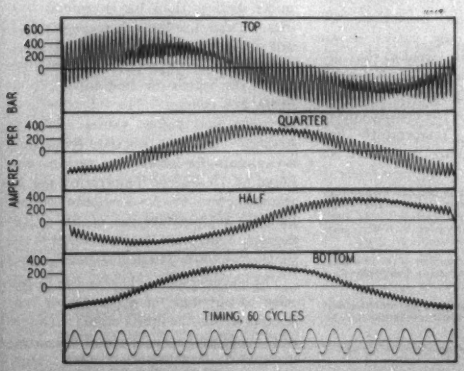


Figure 19. Rotor-bar currents of three-phase eight-pole motor under load with 5.35 per cent slip, 850 rpm, 224 volts, 6.1 amperes

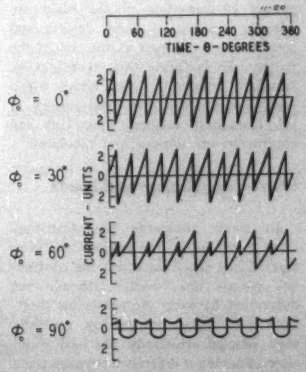


Figure 20. Rotor-bar current at zero slip for three-phase winding with 5/6 pitch

Classification and Co-ordination of Short-Time and Intermittent Ratings and Applications

R. E. HELLMUND
FELLOW AIEE

Synopsis: The paper makes a comparison of permissible temperature rises for short-time and intermittent ratings and permissible rises for continuous ratings. It suggests methods for the application of short-time ratings to various typical classes of intermittent load conditions and presents for each of these classes ways and means for properly co-ordinating the ratings of the major devices (motors and generators) and the ratings of the auxiliary devices and conductors.

Introduction

THE present commercial standards for electrical apparatus and conductors usually provide continuous ratings and short-time ratings for periods of 5, 15, 30, 60, and 120 minutes. The methods used for selecting ratings for various classes of intermittent or varying loads from these available ratings are rather indefinite and at times result in applications which, although generally satisfactory, are often not the most economical. It is shown in this paper that by following essentially the present practices of rating and application but also properly co-ordinating them and supplementing them with additional data, a selection of the most suitable short-time ratings can be made. A very simple procedure applying to the proper co-ordination of the main apparatus and the auxiliary devices and conductors is outlined at the end of the paper. To facilitate this co-ordination, standard temperature-rise values which seem suitable for short-time ratings of the main and auxiliary apparatus and conductors are derived and tabulated.

Short-Time Ratings and Loads

In many standards the short-time ratings are based on temperature rises higher than those on which the continuous ratings are based. Although the differences between the values for short-time and continuous ratings generally were selected arbitrarily, the basic principle of having a difference between them is sound. With short-time loads the maximum temperatures obtained can last for only a relatively small part of the total time. Since the deterioration of insulation depends not only upon temperature but also upon the length of time the higher temperatures prevail, satisfactory life can be obtained if relatively high temperatures prevail for only a small part of the time. Tests have indicated that the life of insulation is halved for each eight- to ten-degree-centigrade increase in temperature, particularly for insulation exposed to oxygen in the air. It is proposed to use this rule here and to calculate for some typical short-time ratings the permissible maximum temperature rises which result in insulation life about equal to that obtained with temperatures specified as standard for continuous operation. (Methods suggested by V. M. Montsinger for transformers[1,2] and also outlined by P. L. Alger and T. C. Johnson[6] will be used for this purpose. These methods and the eight- to ten-degree-centigrade value may not apply to applications where oxygen is excluded, as in oil-insulated transformers with inert air protection or hydrogen-cooled machines.)

Figure 1 shows a number of typical time-temperature curves for short-time ratings of a small induction motor. These curves have been calculated under the assumption that each eight-degree-centigrade increase in temperature halves the life of the insulation. On this basis, each of the curves shown will give insulation life equal to that obtained with a uniform rise of 60 degrees centigrade (by resistance) over the same period of time. Since the cooling curves approach the zero temperature line asymptotically (reaching zero after an infinite time), it was necessary to limit arbitrarily the time for each curve, and the point at which the temperature rise drops to ten degrees centigrade was taken. This provides a margin of safety and results in conservative curves. (All calculations and discussions in this paper deal with temperature rise by resistance; the thermometer method is not very satisfactory for the study proposed.)

It is seen from figure 1 that the permissible temperature rises range from 80 to 93 degrees centigrade, or an excess of 33 to 55 per cent over the 60-degree temperature rise permissible for continuous operation.[10] The use of these higher permissible temperature rises is of importance economically because, according to curve 1, a five-minute rating with a 60-degree limit can be raised to an 11-minute rating for the higher temperature. Similarly, curve 2 shows an increase from a 15-minute to a 46-minute rating; curves 3 and 4 show increases from 30 to 80 minutes and from 38 to 116 minutes respectively. Curve 4 has been chosen as a limiting case with a rate of temperature rise of about one-half degree a minute at 60 degrees centigrade; for major devices such as generators, motors, etc., it is customary to apply continuous ratings rather than short-time ratings if the rate of temperature rise is lower.

The curves of figure 1 are typical of most apparatus, the principal difference being that with larger devices the time values increase. This, however, does not affect the values of the maximum permissible temperatures, which are influenced essentially by the shapes of the curves and which vary to some extent with different types and sizes. Allowing for such variation within usual limits, it seems safe to select for standardization purposes temperature rises 25 to 40 per cent higher for short-time ratings of major devices than for continuous ratings. Table I, column 2, suggests standard values of temperature rise for short-time ratings of major devices corresponding to the values for continuous ratings in the first column. The values are conservative and higher values might be justified. (After testing class *B* insulated d-c motors for short-time ratings now based on 75 degrees temperature rise by thermometer, F. A. Compton recommends a temperature rise of 105 to 120 degrees centigrade by resistance;[4] the table gives 100 or 110 degrees centigrade.)

The considerations thus far can be applied to any type of apparatus or conductors within the limits stated. (Naturally modifications in some of the values mentioned must be made when values

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The author wishes to acknowledge his indebtedness to C. S. Hague, Jr., for his assistance in the calculation of the curves.

1. For all numbered references, see list at end of paper.

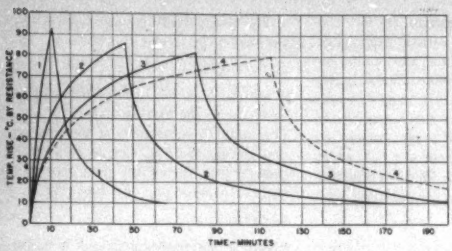


Figure 1. Permissible temperature rises for various short-time loads

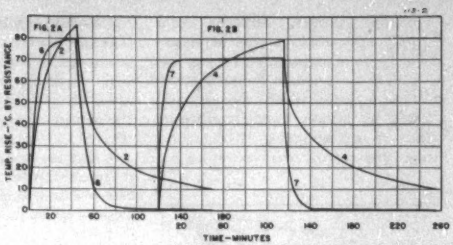


Figure 2. Comparison of permissible temperature rises for short-time loads of apparatus with different time constants

other than 60 degrees permissible temperature rise for continuous load apply.) However, if the main devices are connected in series with various auxiliary devices or conductors having much smaller time constants than the main device, the conclusions derived so far must be modified for the auxiliary devices or conductors. This is demonstrated in figure 2*a*, curve 2 of which corresponds to curve 2 of figure 1 and is considered representative of main devices such as generators, motors, etc. Any smaller device or conductor connected in series with the main device and having a smaller time constant will show more rapid initial temperature rise, and if loaded as long as the main device, will run at temperatures near the maximum for longer periods than the main device. This in turn means that to get equally satisfactory insulation life the maximum temperature-rise values must be kept lower. Curve 6, figure 2*a*, applies to an auxiliary device with a small time constant giving the same insulation life (with the same class of insulation) assumed for the main device. It is seen that 80 degrees centigrade is the maximum permissible value for the auxiliary device instead of 86 degrees centigrade indicated for the main device. Curve 4 in figure 2*b* corresponds to curve 4 in figure 1 and is another typical curve for the main device. Curve 7 has been calculated for an auxiliary device with a smaller time constant to give the same insulation life. Again a smaller maximum temperature rise (71 degrees centigrade) must be chosen for the auxiliary device than the 80 degrees for the main device. Here the auxiliary device reaches constant temperature during the load period.

In view of the conditions just described, it seems advisable to use lower maximum values of temperature rise for the rating of small auxiliary devices and conductors intended for short-time service. This practice need not be altered by the fact that, as in figure 2*b*, the short-time ratings of the auxiliary devices or conductors give the same temperatures as obtained with continuous operation at the same load. The values in column 3 of table I are suggested for the standardization of small auxiliary devices and conductors used in conjunction with main devices in short-time service. In general, where two values are given, the lower value of one column should be used with the lower value of the other column.

Table I. Suggested Relation of Temperature Rises (by Resistance) for Short-Time Ratings to Rises for Continuous Ratings

Continuous Ratings (Deg C)	Short-Time Ratings (Deg C)	
	Main Apparatus	Small Auxiliary Apparatus or Conductors*
20	25	25
25	30 or 35	30
30	40	35
40	50 or 55	45 or 50
50	60 or 70	55 or 60
60 (class *A* insulation)[10]	80	70
80 (class *B* insulation)[10]	100 or 110	90 or 100
100	125	110 or 125

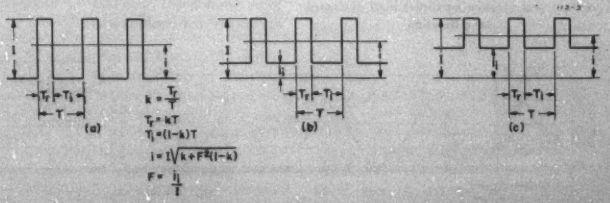
The values in this table are chosen from the preferred values suggested in AIEE Standard number 1.[10] In general they should give satisfactory life of insulation if the rated load is continually reapplied after the apparatus temperature has dropped to about ambient temperature. Practical cases of application of this kind are rare. As a rule, considerable time elapses between the applications of loads, and whenever this is the case the application of apparatus can be made so as to reach even higher temperature-rise values than those suggested for standard rating purposes in the table. Although the value of 80 degrees centigrade suggested in the table to correspond to 60 degrees rise for continuous load does not take full advantage of the permissible rises indicated in figure 1, the increases in time over the 60-degree values are still appreciable, ranging from 65 to 250 per cent.

*These values also may be used if the short-time operation of small auxiliary apparatus or conductors results in the same temperature rise obtained with continuous operation at the same load.

Intermittent and Varying Loads

Typical intermittent and varying load cycles are illustrated in figure 3. During the time (T_r) the apparatus is heavily loaded and carries a current (I), while for the remaining period (T_l) it may carry no load, as in the case of a welding generator[9] (figure 3*a*). Figure 3*b* represents such apparatus as a-c induction motors, which are loaded during the period (T_r) and not loaded during (T_l), but which have to carry a magnetizing current (i_l) during the off periods. There is little change in principle if the motor, instead of carrying a magnetizing current, carries a light load (i_l) as indicated in figure 3*c*. This might occur with an industrial mill which is driven light during (T_l) and loaded during (T_r). In all the applications cited, the rms current (i) is, of course, less than the current (I) during the heavy-load period. (In this discussion, service conditions as illustrated in figures 3 and 10 are of the type which as a rule can be handled by devices having

Figure 3. Typical intermittent and varying (periodic) load cycles



"short-time" ratings. Although many of the considerations in the paper are applicable to other cases, no attempt has been made to include a complete study of varying loads which are generally handled by devices having continuous ratings or a combination of continuous ratings and certain overload ratings.)

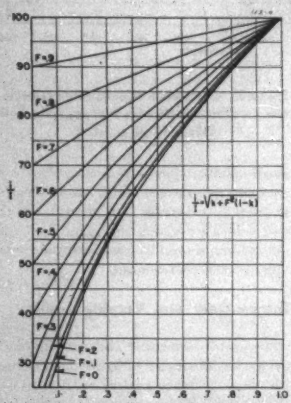


Figure 4. Ratio of rms current to load current for intermittent and varying load cycles

Very often the current (I) during the load period is a significant value in machine design for considerations other than heating. A commutator machine, such as a welding generator[8] for instance, must be able to commutate the current (I) satisfactorily during long periods of machine operation. In an induction motor the value (I) is equivalent to a torque required for driving the load and it is necessary that the pull-out and starting torques of the motor have certain definite relations to the running torque if satisfactory operation and a sufficient margin of safety are to be obtained. Again, the value (I) may be of significance in the regulation of the machine or apparatus. In these examples, current (i) is of importance only in the heating of the machine, while current (I) has considerable bearing on various other characteristics, including the mechanical design. It should therefore appear in the rating structure and it is suggested that the nominal rating of the apparatus be selected to correspond to the current (I) and that the heating current (i_h) which it can carry within safe limits of temperature rise continuously, be indicated by a suitable service factor

$$S_1=\frac{i_h}{I} \tag{1}$$

This has been previously suggested by others (Alger,[4,6] Johnson,[5,6] and Hildebrand[7]) and seems to be a simple method for supplying fairly complete information about heating as well as other characteristics of practical importance. It has also been suggested that no reference whatsoever be made to temperature conditions in connection with the nominal rating corresponding to current (I).[6] However, since practically all nominal ratings of electrical apparatus are now tied in with temperature considerations in some way or other, it seems desirable to retain the temperature rating as the primary basis for all nominal ratings. This can very readily be done because current (I), although it cannot be carried continuously with many devices, can always be carried for at least limited periods and be tied in with one of the standard short-time (5-, 15-, 30-, 60-, or 120-minute) ratings. In this way the length of time the machine can carry the current (I), starting with the machine cold, is indicated. This additional information makes it possible to select for all applications the proper wiring and devices connected in series with the main apparatus, which is very essential for an economical and successful combination of all parts of the circuit. (If the conditions are such that any of the factors, such as commutation, torque, regulation, etc., call for a main device which can carry the current (I) continuously, it can be given a continuous rating (I) and the methods described here will then be of no practical importance with reference to the main apparatus. However, they may be of assistance in the most economical selection of auxiliary apparatus and conductors.)

The rms current (i), dependent upon the load cycles shown in figure 3, is

$$i=I\sqrt{k+F^2(1-k)} \tag{2}$$

in which (k) is the ratio of the load period (T_r) to the total period of the cycle (T), and (F) is the ratio of the rms current during the low-load periods to the rms current during the heavy-load periods. In figure 3*a*, with $F=0$, we have

$$i=I\sqrt{k} \tag{3}$$

Figure 4 has been calculated from formula 2 and gives the rms current for any value of k and F.

With the regularly repeating (periodic) load cycles shown in figure 3, it is evident that the drop in temperature during each light- or no-load period must at least equal the rise in temperature during each heavy-load period in order to obtain a stable cyclic temperature condition in which permissible temperature values are not exceeded. (See figure 5.) It follows directly that with a heavy-load period (T_r), a time (T_i) must be allowed for the light- or no-load period, resulting in a total time (T) for each cycle. With the time-temperature curves A and B fixed by the loads and apparatus characteristics, the maximum ratio of $T_r/T=k$ is definitely limited. It is dependent upon the ratio (R) of the average rate of drop (B_1) to the average rate of rise (A_1) and follows from

$$k=\frac{R}{1+R} \tag{4}$$

These relations are basic to all regularly repeating (periodic) intermittent or varying loads. A more complete outline of this method of analysis by time-temperature curves is given in a previous paper.[3] In that paper it was generally assumed that the peak temperature rises reached with short-time ratings and during intermittent loads should be the same as the permissible temperature rises for continuous loads. This, however, does not take advantage of the fact that the latter temperature may be safely exceeded for limited periods. An attempt will therefore be made in the following to take advantage of this possibility for

Figure 5. Temperature variation with intermittent and varying (periodic) load cycles of long duration

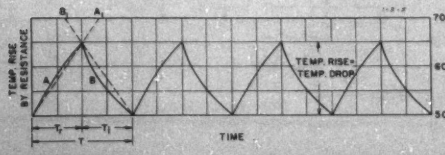
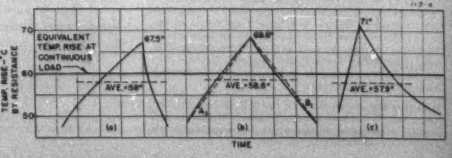


Figure 6. Permissible temperature rises for typical periodic loads



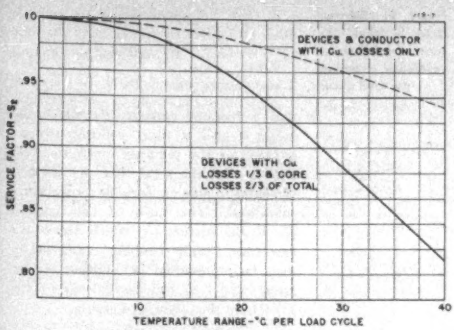

DEVICES & CONDUCTOR WITH Cu. LOSSES ONLY
DEVICES WITH Cu. LOSSES 1/3 & CORE LOSSES 2/3 OF TOTAL
SERVICE FACTOR-S_2
TEMPERATURE RANGE-°C. PER LOAD CYCLE

Figure 7. Service factor S_2 takes into account the amplitude of the cyclic temperature variation

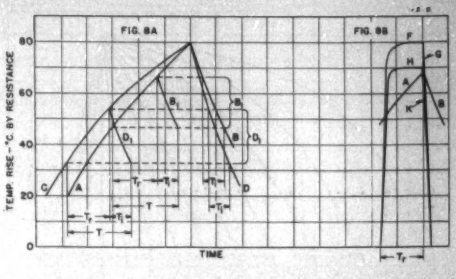


Figure 8. Comparative analysis of temperature conditions for apparatus of different time constants during periodic load cycles

intermittent load applications as in figure 5.

Class 1A Intermittent Service

For this class of service it is assumed that the ventilation conditions are not appreciably changed between the heavy-load and the light- or no-load periods. This applies to most stationary devices or conductors unless they are equipped with adjustable forced ventilation; it also applies in general to constant-speed machinery while running. It is further assumed that the load periods are rather short and the variation in temperature rise will be so small that it can be neglected.

Since with these assumptions the temperature of the machine is about constant, the value (i) should be such as to give a safe temperature rise for continuous operation. For this type of service it is therefore necessary merely to select apparatus having a short-time nominal rating (I) with a service factor at least equal to

$$S_1 = \frac{i}{I} = \frac{i_h}{I} \qquad (5)$$

The method outlined under class 1A should be satisfactory if its use is confined to applications where the heavy-load period is limited to ten per cent of the time (T_r) on which the nominal rating is based; that is, in the case of a 30-minute rating, for instance, the load period (T_r) does not exceed three minutes. Then the total temperature variation during the cycle will as a rule be less than ten per cent of the temperature rise for continuous operation and the excess temperature will be less than five per cent.

The wiring and auxiliary devices connected in series with the main machine or apparatus usually have smaller time constants. Therefore, their temperature variations in percentage of the average temperature rise during the time periods just indicated may be larger. This makes it advisable to select them for a continuous rating five to ten per cent larger than the rms value of the load.

Class 2A Intermittent Service

For class 2A applications, it is assumed that the cooling conditions are essentially the same during the entire load cycle but that the time for each cycle is increased to the point where the variations in temperature can no longer be neglected. Figure 6 shows three typical time-temperature curves, each for a single cycle with a total temperature change of 20 degrees centigrade. These curves also have been calculated to give a life of insulation equivalent to that obtained with continuous operation at 60 degrees centigrade rise. Figure 6*b* has a curvature in the rising curve about equal to that of the dropping curve. This means that the results are the same as they would be with the triangular time-temperature curve A_1B_1. The maximum permissible temperature rise is 68.6 degrees centigrade. With curves 6*a* having more curvature in the rising curve and thus giving longer periods for the higher temperatures, the maximum must be kept lower, that is to about 67 degrees centigrade. The opposite condition shown in 6*c* led to a higher maximum of 72 degrees centigrade. The average of the temperature rises for these cycles varies within the narrow range of 57.9 to 58.6, that is, 1.4 to 2.1 degrees centigrade, or 2.3 to 3.5 per cent below the temperature-rise value for continuous load. Thus, in order to obtain satisfactory operation the losses must be lowered 2.3 to 3.5 per cent. In devices having only copper losses, this means a reduction of only 1.1 to 1.7 per cent in rms current. In machines designed for intermittent service the core losses are often relatively high, and therefore the copper losses may be as low as one-third of the combined losses. The same reduction in total losses may therefore require a reduction of about 7 to 10.5 per cent in the copper losses, which means 3.5 to 5.5 per cent reduction in the rms current. This is too liberal because the influence of the core losses upon the copper temperature is usually much less than that of the copper losses. It would thus seem that an allowance of five per cent, or a service factor $S_2 = 0.95$, to cover the difference between case 1A and 2A would be quite safe for a variation of 20 degrees centigrade. The curve for S_2 in figure 7 has been based on this line of reasoning and covers the range of temperature variations usually found in practice.

Determination of the exact temperature variation would require a complete time-temperature curve analysis. It can be safely assumed, however, that it usually does not exceed the value $r(T_r) \div (T_s)$ in which T_r = the time of heavy load per cycle, T_s = the time used as a basis for the short-time rating, and r = the temperature rise upon which this rating is based. It is thus possible to calculate safe maximum limits for the temperature variation and then find the value S_2 for this cycle from figure 7. The service factor for class 2A applications is then

$$S = S_1 S_2 \qquad (6)$$

The application of smaller auxiliary devices and conductors with main devices in intermittent service of this class cannot be made safely by the method outlined under class 1A. Depending upon their time constants, the temperature

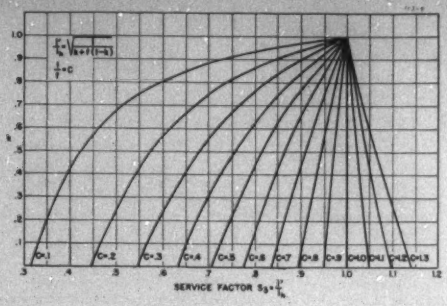


Figure 9. Service factor S_3 takes into account variations in ventilation during the load cycle

rises of the auxiliary devices and conductors may vary over wide ranges and it is hardly feasible to set any safe practical limits for the variation.

Two distinctly different typical conditions are shown in figure 8. In figure 8*a* we have heating curve *A* and cooling curve *B* for a main device. An auxiliary device with smaller time constant and designed for the same short-time temperature rise will have a flatter curve (*C*) for the upper part of the heating curve, and a steeper curve (*D*) for the cooling curve. With a load time (T_r) and idle time (T_i), stable repeating conditions are obtained with a maximum temperature rise of 68 degrees centigrade for the main device and 54 degrees centigrade for the auxiliary device, as found by the methods described in a previous paper.[2] It follows that with conditions shown in figure 8*a*, the auxiliary device will have lower temperature rises than the main device if based on the same temperature rise for the same short-time rating.[9] Entirely different results are obtained if the time constant of the auxiliary device or conductor is so small that maximum temperature is reached during the time (T_r), as shown by curve *F*, figure 8*b*. It is at once evident that with curves *F* and *G* of the auxiliary device or conductor, insulation life will be shorter than with curves *A* and *B* of the main device. This undesirable condition can be largely eliminated by lowering the rating temperature of the auxiliary device or conductor as suggested under short-time ratings in column 3, table I and illustrated by curves *H* and *K* in figure 8*b*. It can therefore be concluded that for intermittent service of this 2*A* class, the auxiliary devices and conductors having the same short-time ratings as the main device can be selected if ratings are based on

(*a*). The same temperature rises (column 2, table I) as the main device, if the auxiliary device does not reach its maximum temperature during the load period (T_r);

(*b*). A somewhat lower temperature rise (column 3, table I) if the auxiliary device reaches its maximum temperature during the load period (T_r).

In general, conditions under (*a*) will apply to all except very small auxiliary devices, while conditions under (*b*) may be found to apply frequently to conductors. If suitable temperature rises, as indicated here, are used in the standardization of devices and conductors for intermittent service, their application becomes exceedingly simple and consists merely in combining apparatus and conductors having the same short-time rating with reference to current and time.

Class 1B Intermittent Service

In some classes of application, ventilation conditions are considerably different during the periods of heavy and light load or no load. This is true in any case where artificial cooling is automatically stopped, except during the heavy-load period. A more common application is represented by motors carrying a current (*I*) while loaded and running and which stand still during idle periods. In these applications the rate of cooling is usually reduced because of the reduced ventilation, although with motors standing still this is at least partially compensated by the absence of those losses (essentially core losses) occurring with the motor running light. In some applications, especially enclosed motors, the elimination of losses may more than counteract the reduced cooling.

If the ratio of the cooling rate for class 1*A* to that for class 1*B* during no-load periods is assumed to be (*f*), it follows that the necessary drop in temperature for each cycle can be obtained for class 1*B* if the no-load time is increased from T_i to $T_i^1 = fT_i$. Consequently, we can analyze class 1*B* applications the same as class 1*A* merely by substituting the time (T_i^1) for (T_i). By replacing in formulas 2 and 3 the value k by $k^1 = \frac{T_r}{T_r + T_i^1}$, we find a reduced current (i^1) which the motor is able to carry continuously regardless of the reduced ventilation, assuming that the total time per cycle is too short to give appreciable temperature variations. The ratio of this current (i^1) to the current (i_h) which the motor can carry while running continuously may be represented by another service factor (S_3). It can be calculated for $F=0$ from the following formula

$$S_3 = \frac{i^1}{i_h} = \sqrt{\frac{T_r + T_i}{T_r + fT_i}} = \sqrt{\frac{1}{k + f(1-k)}} \qquad (7)$$

Figure 9 gives this service factor for various values of k and f. With the aid of these curves the current (i_h) can be found directly from the smaller actual rms current (i^1). The total service factor for class 1*B* applications is, therefore, $S = S_1 S_3$. Suitable values for (f) can be determined by the test method described in a previous paper,[3] taking cooling curves with the motors running and at rest. The method here outlined for class 1*B* motors should be satisfactory if the running time per cycle does not exceed ten per cent of the rating time (T_a).

The application of conductors and auxiliary devices follows the same general principle as suggested for class 1*A*, using the actual rms current as a basis. This, of course, is under the assumption that the cooling conditions of the conductors and auxiliary devices are the same for both the load and the idle period, which is generally true.

Class 2B Intermittent Service

For class 2*B* applications it is assumed that the ventilation is different for the high-load and the low-load or no-load periods, but that the time for each load cycle is so long that temperature variations become of practical importance. Thus, class 2*B* applications have the same relation to class 1*B* as class 2*A* have to class 1*A*. It is therefore necessary to introduce, in addition to the service factor (S_3), the service factor (S_2), which leads to the service factor

$$S = S_1 S_2 S_3 \qquad (8)$$

If auxiliary devices and conductors are combined in this service with the main devices by the methods suggested for class 2*A* applications, they will as a rule have an unnecessarily large margin of safety. The reason for this is that the

cooling conditions of the auxiliary devices and conductors usually remain unchanged, while those of the main device are reduced during the ideal periods. However, it is not safe to suggest any other practice which is generally applicable. In specific applications, with known conditions and additional analysis, further economies may be accomplished, but as a rule the gains possible will be of minor importance in the total cost.

General Discussion of Service Factors

S_1 indicates the ratio of the current giving a safe temperature rise with continuous operation to the current corresponding to the nominal (short-time) rating. It is governed by the design of the apparatus and the temperature rises used as a basis for short-time and continuous ratings; it must be determined by test. Minimum values for (S_1) should be known and be standardized for certain types, classes, and ranges of ratings, the same as is done with torque ratios. This is exemplified in table II.

Table II

5-minute ratings	$S_1 = 0.50$
15-minute ratings	$S_1 = 0.60$
30-minute ratings	$S_1 = 0.70$
60-minute ratings	$S_1 = 0.80$
120-minute ratings	$S_1 = 0.87$

S_2 makes allowance for temperature variation during long load cycles. It is governed partly by the type of application and partly by the design of the apparatus. However, since it does not vary widely, it can be shown with sufficient accuracy for most practical purposes by curves as shown in figure 7. As pointed out there, higher values than those indicated for S_2 in the full-line curve apply to cases where the copper losses essentially govern the temperature rise of the windings (dotted curve in figure 7).

S_3 makes allowance for differences in ventilation which may exist between the heavy-load and the light- or no-load periods. It is influenced by both the type of application and characteristics of the apparatus. The influence of the former is covered in formula 7 by the factor (k) determined from the service condition. The factor (f), depends upon the apparatus characteristics. It is not recommended here that (f) be made a part of the rating structure but that for various types of motors, values for (f) be established which are safe but which do not result in uneconomic applications.

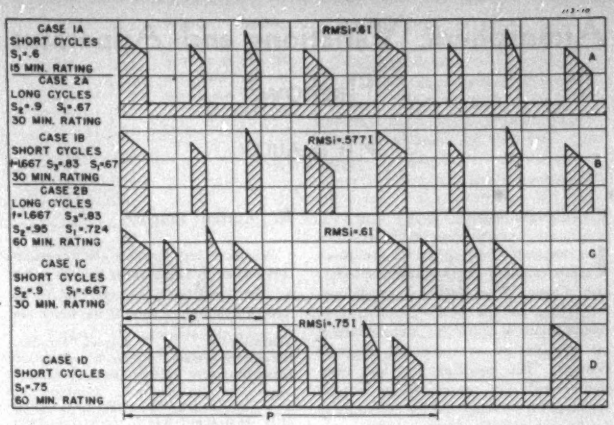


Figure 10. Some typical load cycles analyzed by the methods suggested

Selection of Short-Time Ratings for Intermittent or Varying Loads

(a). Main Apparatus

The variety of conditions met in practice makes it impossible to outline a method of application suitable under all circumstances. However, the data presented here are suitable for the majority of applications and should prove helpful in giving results quickly. Both periodic load cycles as shown in figure 3 and load cycles with irregular intermittent loads as in figure 10 can be calculated as follows.

Divide the entire time into high- and low-load or no-load periods; then calculate the rms current for all the high-load periods. The resultant value is the current (I) of our previous analysis and it is used for the selection of the current value of the nominal short-time rating (or horsepower or kilowatt ratings corresponding to this current value).

The current value (i_t) previously used is found by calculating the rms current for all the low-load periods and it permits the calculation of $F = i_t/I$. The value (k) is obtained by dividing the time of all high-load periods by the total time. The resultant actual rms current (i) can now be found from formula 2 or figure 4. From here on we have to distinguish between different classes of applications.

Class 1A: If with a load as shown in figure 3 or 10*A* the ventilation is essentially constant and the load periods short, find i/I. Then select from such tables as table II the nominal short-time rating for the current I which has a value S_1 at least equal to i/I.

Class 2A: If, again, with the load as shown in figure 3 or 10*A* the ventilation is essentially constant but the periods for some of the heavier loads are long, find S_2 from figure 7; determine i/S_2I, and select a rating having a value (S_1) which is at least equal to i/S_2I.

Class 1B: If the ventilation changes between heavy- and light- or no-load periods and the load periods are short (figure 3*a* or 10*B*), find S_3 from formula 7 or figure 9, determine i/S_3I, and select a rating at least equal to i/S_3I.

Class 2B: If the ventilation changes between heavy- and light- or no-load periods and some of the periods for the heavier loads are long, find both S_2 and S_3, determine i/S_2S_3I, and select a rating with S_1 at least equal to i/S_2S_3I.

If the load cycles are distributed rather unevenly in time as in figure 10*C*, it is evident that there will be some fluctuation in the temperature rise even though the individual load cycles are very short. If the periods (P) over which the load cycles are distributed are shorter than the rating time of the device, the use of a service factor of the general order of S_2 will give reasonably correct results. If, on the other hand, the period (P) is rather long as shown in figure 10*D*, it is safer to calculate results under the assumption that the load conditions prevailing during (P) are continuous. The loads in figures 10*A* to 10*D* have all been assumed to have the same value (I) and thus the same nominal current rating. It will be interesting to note the rms values of i/I and S_1 in figure 10 and the time values to be

Atmospheric Variations and Apparatus Flashover

P. H. McAULEY
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I. Introduction

IN practically all electrical apparatus use is made of the insulating properties of air. The electrical breakdown strength of air, for the electrode arrangements found in apparatus, depends upon air temperature, pressure and moisture content. This condition has long been appreciated and recognized in various standards for testing and for determining insulation ratings. However, the range and significance of the extreme conditions encountered, is not always appreciated. It is proposed, therefore, to consider the variations found in actual service and determine how well current standards and application practices cover these variations. In addition, the desirability of uniform application practices and reference ranges for different apparatus is suggested.

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1. For all numbered references, see list at end of paper.

II. Current Practice

Wherever test margins are important, test values obtained under various actual weather conditions are corrected to the American standard conditions, which are:

Temperature	77 degrees Fahrenheit
Barometric pressure	29.92 inches of mercury
Humidity	0.6085 inches of mercury

According to most apparatus standards, equipment which meets the specified voltage tests, corrected to these conditions, may be used at any of the temperature and humidity conditions encountered in nature and at any barometric pressure encountered at altitudes up to 3,300 feet. The corrections for different air conditions are in many cases quite large and the actual flashover voltage of a piece of equipment in service may differ by as much as 25 per cent from the value for standard test conditions. The internal insulation of apparatus is not affected by the changing dielectric strength of the ambient air and in some cases the internal insulation may not be applied effectively and economically because of this situation. On the other hand, the internal insulation may be overstressed when conditions of unusually high external flashover prevail. Thus the variations in air conditions also are of some concern to the designer in that equipment insulation must be suitable for the most unfavorable conditions encountered in use.

III. Temperature, Pressure, Humidity

(a). Temperature

Flashover (and sparkover) voltages through air vary inversely with the absolute temperature. Figure 1 shows the variation in per cent for temperature ranges encountered in the U.S.A.

(b). Barometric Pressure

Flashover voltages vary directly with the barometric pressure. In a given location the pressure ordinarily does not vary through more than a five per cent range. However, barometric pressure and the dielectric strength of air do vary with altitude. Figure 2 indicates the relation.

(c). Humidity

Flashover voltages for nonhomogeneous dielectric fields vary with the absolute humidity of the air. The change in these voltages depends upon wave form, polarity, and the kind of apparatus tested. Correction curves, of which figure 3 is typical, must be obtained experimentally.

(d). Relative Air Density

The effect of temperature and of pressure have been combined into a single

chosen for the ratings; the latter range from 15 to 60 minutes for the various service conditions.

(b). Auxiliary Devices and Conductors

For all classes of applications discussed under "main devices," safe temperature rises are obtained for the auxiliary devices and conductors if they are rated for the same current value (I) and the same time as the main apparatus, assuming that the method of establishing short-time ratings outlined under class 2A is followed. For applications 1A and 1B with short-load periods which are definitely limited by the type of application, further economies can be safely effected by selecting auxiliary devices and conductors having continuous ratings corresponding to the actual rms values, as discussed under 1A and 1B.

Obviously, all the methods outlined here may have to be modified in extreme or unusual cases which depart from the assumptions and limitations indicated in the paper.

Conclusions

The selection of the most suitable and economical short-time ratings of main devices, auxiliary devices, and conductors, all properly co-ordinated, has been reduced to an extremely simple procedure for many of the intermittent and varying loads found in practice. Uncertainties and uneconomical combinations previously encountered can be eliminated by the co-ordinated practices suggested for rating and application.

References

1. Effect of Load Factor on Operation of Power Transformers by Temperature, V. M. Montsinger. AIEE Transactions, volume 59, 1940 (November section), pages 632–6.

2. Temperature Limits for Short-Time Overloads for Oil-Insulated Neutral Grounding Reactors and Transformers, V. M. Montsinger. AIEE Transactions, volume 57, 1938 (January section), pages 39–44.

3. A Study of Short-Time Ratings and Their Application to Intermittent Duty Cycles, R. E. Hellmund and P. H. McAuley. AIEE Transactions, volume 59, 1940, pages 1050–5.

4. Discussion of reference 3, P. L. Alger. AIEE Transactions, volume 59, 1940, pages 1221–2.

5. Discussion of reference 3, T. C. Johnson. AIEE Transactions, volume 59, 1940, pages 1222–3.

6. Rating of General-Purpose Induction Motors, P. L. Alger and T. C. Johnson. AIEE Transactions, volume 58, 1939 (September section), pages 445–56.

7. Duty Cycles and Motor Rating, L. E. Hildebrand. AIEE Transactions, volume 58, 1939 (September section), pages 478–83.

8. The Application of Class B Insulation to Auxiliary Type D-C Motors in Severe-Duty Service, F. A. Compton, Jr. AIEE Transactions, volume 59, 1940, pages 828–34.

9. Report on Standards Conference at 1940 AIEE Summer Convention, Electrical Engineering, volume 59, August 1940, pages 337–8.

10. AIEE Standard No. 1, General Principles Upon Which Temperature Limits Are Based in the Rating of Electrical Machinery and Apparatus, June 1, 1940.

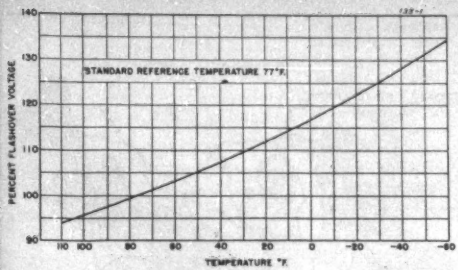


Figure 1. Flashover voltages vary through a range of over 30 per cent due to temperature changes of ambient air

factor, known as relative air density, which is unity for the standard conditions of temperature and pressure. For other conditions the relative air density is

$$\frac{17.95 \times \text{bar. press. (inches)}}{460 + \text{temp. degrees Fahrenheit}}$$

Flashover voltages actually vary at a rate less than the relative air density, but for practical purposes, the slightly pessimistic assumption that they follow the relative air density directly is satisfactory.[1]

(e). Magnitude of Changes

It is seen that temperature alone may produce a change in flashover voltage of 30 per cent. An elevation of 3,300 feet reduces flashover voltage 11 per cent, neglecting daily variations. Annual variations in humidity cause a change in flashover through a 20 per cent range. These effects, therefore are important and their combined results are of interest.

IV. Service Conditions

(a). Temperature

Temperatures in the continental U. S. vary from 120 degrees Fahrenheit to −50 degrees Fahrenheit. In terms of the variation from 100 per cent flashover at 77 degrees Fahrenheit, these correspond to −8 per cent and +31 per cent change. Maximum and minimum temperatures for some typical cities, where high voltage apparatus may be used, are given in table I.

(b). Barometric Pressure

An altitude map of the U.S.A. is shown in figure 4. Maximum and minimum altitudes by states are given in table II. It follows that a considerable part of the western states is above the 3,300-foot level to which standard apparatus is applicable. From table I also, the elevations of the cities listed range up to 7,000 feet. Consequently, a good deal of equipment is installed at altitudes above the standard range of 3,300 feet.

(c). Humidity

In general, the absolute humidity is lowest at low temperatures, where the air becomes saturated at very low moisture contents. For locations near large bodies of water high temperatures and high humidities tend to coincide and these two factors tend to cancel in their effect on flashover. However, table I indicates

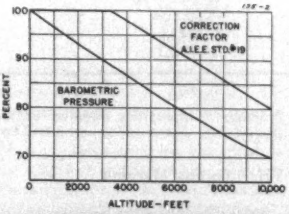


Figure 2. Flashover voltages vary directly with the barometric pressure which is 70 per cent of mean sea level pressure at 10,000 feet altitude

that, for the high inland locations, absolute humidities are quite low, even at times of maximum temperature, at Denver, for example.

(d). Combined Effects

The change in flashover voltages for these extreme conditions in certain cities has been calculated and is shown in table III. The range of the variations likely to be encountered in extreme cases is around 27 per cent. Attention is called, however, to Great Falls, Montana, which is just below the 3,300-foot altitude limit. At this location, standard apparatus would at times suffer a reduction in flashover strength of practically 25 per cent. It should be pointed out that variations in barometric pressure and in humidity from the values assumed or recorded might influence the figures given another two or three per cent in either direction.

V. Rain, Fog, Dirt, Salt Spray

In addition to encountering a reduction in the dielectric strength of air, electrical insulating surfaces, such as porcelain bushings and insulators, frequently are subjected to rain, fog, and foreign deposits. A heavy rain will reduce the flashover voltage of a new clean insulator 30 per cent. Fog or rain on a dirty insulator may reduce the effectiveness of the insulator to the point where operation at rated voltage is impaired. In such cases special types of insulation may be applied or periodic cleaning may be found necessary. Wanger[2] and others have presented quantitative data on this subject, which is outside the scope of this paper.

VI. Apparatus

For a practical illustration of apparatus application, bushings will be considered. The basic insulation levels, based on an impulse voltage-withstand test, for different voltage classes have been suggested for standardization.[3] These levels are shown in figure 5, with the reduced corresponding values for altitudes of 5,000 and 10,000 feet. For the higher voltage classes, the next higher voltage class applies quite well for steps in elevation of the order of 3,000 to 5,000 feet. From 15 to 69 kv the insulation steps do not lend themselves as readily to this practice. Naturally, in any practical application compromises must be made between maintenance of insulation levels and subjecting internal insulation of apparatus to excessive voltages. To avoid an excessive number of designs, it probably is

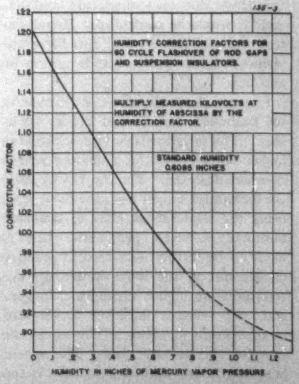


Figure 3. Flashover voltages vary with absolute humidity. The annual range is over 20 per cent for locations at moderate altitudes

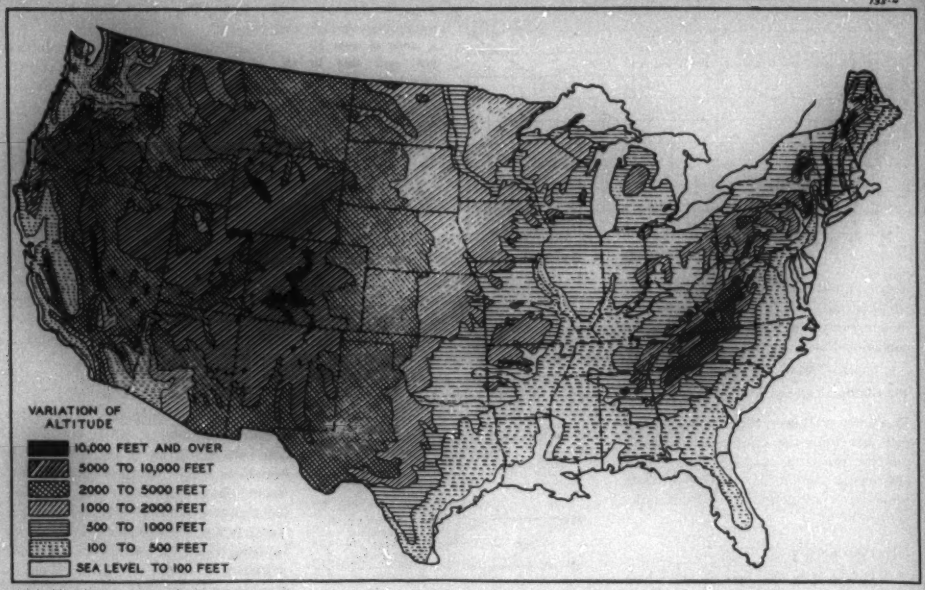

VARIATION OF ALTITUDE
10,000 FEET AND OVER
5000 TO 10,000 FEET
2000 TO 5000 FEET
1000 TO 2000 FEET
500 TO 1000 FEET
100 TO 500 FEET
SEA LEVEL TO 100 FEET

Figure 4. The mean elevation of the United States, including Alaska, is 2,500 feet. About 8.3 per cent of the earth's land lies above 6,000 feet and about 2.5 per cent is above 12,000 feet elevation

most economical to use the next largest bushing with a gap to reduce its flashover at the altitude in question to the basic insulation level of the apparatus. The variations due to temperature and humidity cannot be controlled. Hence, excessive approximations in apparatus application for a given altitude are to be avoided.

Figure 6 shows the effect of altitude on the flashover of 34.5- and 115-kv bushings. The relative flashovers of the next higher voltage steps in 3,300-foot ranges also are indicated. For the 115-kv case, the maximum spread from the basic level using the next higher class of standard bushings is seven per cent. This is likely to be further decreased in practice on account of the lower humidities encountered at higher altitudes. In general, the relative flashover levels lead to a fortunate situation. This is not the case for the 34.5-kv class. The spread between the 46- and 69-kv classes is too great for application in the simple manner found above. For this reason, it has been the practice to use "high-altitude" bushings of appropriate flashover in this range.

VII. Testing Margins

Since apparatus is now tested on a withstand voltage basis, all equipment has a small margin over the basic levels to avoid troubles in acceptance tests. These margins, of course, raise the actual flashover range in terms of voltage. However, although the mean flashover is thereby raised, the width of the band due to atmospheric variations remains the same. The net result is that the internal insulation may be worked a little harder in actual service.

VIII. Upper Air Investigations

A subject of increasing interest is the weather conditions at high altitudes above the ground. Figure 7 gives some early data[7] on this point. Temperature pressure and humidity decrease with altitude, of course. However, the very rapid decrease in absolute humidity and the low moisture content at an altitude of 20,000 feet even with a high value at sea level are very striking.

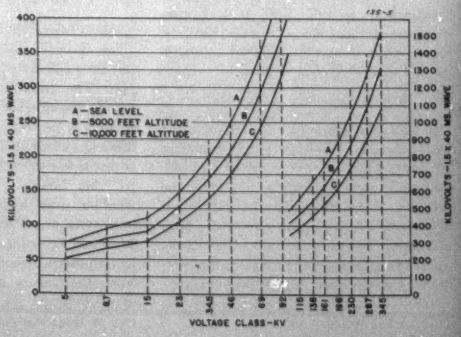


Figure 5. The impulse-withstand voltage ratings of bushings are affected as shown at the 5,000- and 10,000-foot levels

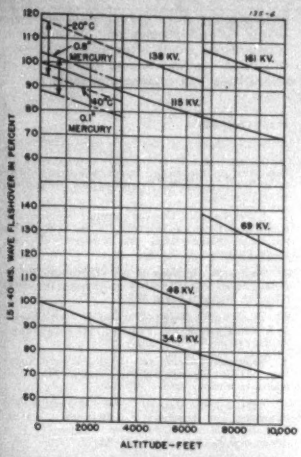
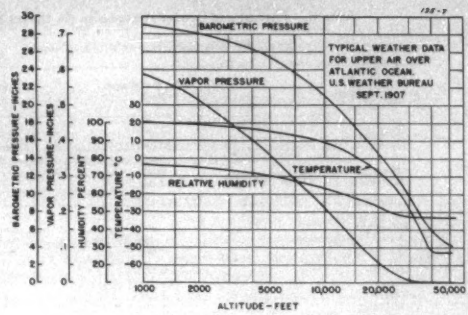


Figure 6. The relation of adjacent voltage classes of apparatus permits applying the next higher classes for different altitude ranges in the higher voltage cases and not in the lower operating voltage classes

Figure 7. Upper air investigations give the variations in weather conditions with altitude. Conditions change of course, with geographical location and with the seasons and time of day



IX. Apparatus Standards

As already stated, apparatus standards permit apparatus of standard voltage rating for elevations up to 3,300 feet. AIEE Standard No. 19 for oil circuit breakers states, "for application at altitudes greater than 3,300 feet, it is recommended that the standard voltage rating of the apparatus should be multiplied by the following factors to obtain the modified voltage rating."

Altitude in Feet	Correction Factor
3,300	1.00
4,000	0.98
5,000	0.95
10,000	0.80

These recommended corrections are shown in figure 2 and their actual relation to the decreasing barometric pressure can be seen. There are a few exceptions to the 3,300-foot standard range, based on thermal rather than flashover limitations. Railway motors, AIEE Standard No. 11, may be used through a range up to 4,000 feet. NEMA Industrial Control Standard gives a range of 6,000 feet and a derating factor for the 6,000–15,000-foot range. These are practical figures based on much experience which help to simplify application problems. However, the adoption of a multitude of ranges as a result of selecting the optimum for each type of apparatus is not to be recommended.

X. Conclusions

1. Temperature changes of the ambient air in the U.S.A. change the flashover voltage of apparatus through a range of 39 per cent.

2. An elevation of 10,000 feet reduces flashover voltages 30 per cent from those at sea level.

3. Variations in absolute humidity result in changes in flashover voltage of nearly 20 per cent.

4. In any one location the combined ef-

Table I. Unusual Air Conditions for Certain Cities of the U.S.A.

Place	Elevation, Feet	Highest-Lowest Temperatures Ever Recorded, Degrees Fahrenheit		Highest Wet Bulb at Noon During July and August for a Six-Year Period			Highest Dry Bulb at Noon During July and August for a Six-Year Period			Mean Relative Humidity at Noon in July
				Dry	Wet	Vapor Pressure*	Dry	Wet	Vapor Pressure*	
Albuquerque, N. M.	4,930	104	−10							
Amarillo, Tex.	3,676			88	74	0.689	100	70	0.402	
Bismarck, N. D.	1,690			90	76	0.747	111	70	0.278	46
Boise, Idaho	2,705	121	−28	93	72	0.55	104	63	0.184	26
Butte, Mont.	5,485	100	−52							
Cheyenne, Wyo.	6,088	100	−38							40
Denver, Col.	5,292	105	−29	92	65	0.319	98	61	0.126	35
El Paso, Tex.	3,775	106	− 5	90	70	0.447	99	67	0.307	33
Flagstaff, Ariz.	6,935	99	−25							
Grand Forks, N. D.	830	108	−43							
Great Falls, Mont.	3,200	107	−49							
Jacksonville, Fla.	100	104	10	98	82	0.921	98	82	0.921	63
Kansas City, Mo.	730	111	−22	98	80	0.829	108	74	0.463	51
Minot, N. D.	1,557	109	−49							
Phoenix, Ariz.	1,075	118	16							30
Pueblo, Col.	4,665	104	−27							33
Reno, Nev.	4,500	106	−19	94	66	0.330	99	65	0.240	18
Salt Lake City, Utah	4,360	105	−20	97	69	0.399	99	63	0.176	29
Sioux Falls, S. D.	1,425	110	−42							
Sante Fe, N. M.	7,013									
Yuma, Ariz.	141	120	22							27

Temperatures from "Air Conditioning Engineer's Atlas," The Industrial Press, New York.

*Vapor pressures correspond to temperatures shown for 30-inch barometric pressure.

Table II. Highest and Lowest Altitudes in the United States

(From the United States Geological Survey)

State or Territory	Highest Altitude, Feet	Lowest Altitude, Feet
Alabama	2,407	Sea level
Alaska	20,500	Sea level
Arizona	12,611	100
Arkansas	2,800	55
California	14,501	276 (below sea)
Colorado	14,402	3,350
Connecticut	2,355	Sea level
Delaware	440	Sea level
District of Columbia	420	Sea level
Florida	301	Sea level
Georgia	4,768	Sea level
Idaho	12,078	720
Illinois	1,241	279
Indiana	1,210	316
Iowa	1,800	477
Kansas	4,135	700
Kentucky	4,100	257
Louisiana	400	Sea level
Maine	5,273	Sea level
Maryland	3,340	Sea level
Massachusetts	3,505	Sea level
Michigan	2,023	573
Minnesota	1,920	602
Mississippi	600	Sea level
Missouri	1,750	210
Montana	12,850	1,800
Nebraska	5,350	825
Nevada	13,058	470
New Hampshire	6,293	Sea level
New Jersey	1,809	Sea level
New Mexico	13,306	2,876
New York	5,344	Sea level
North Carolina	6,711	Sea level
North Dakota	3,500	790
Ohio	1,550	425
Oklahoma	4,750	300
Oregon	11,225	Sea level
Pennsylvania	3,136	Sea level
Rhode Island	805	Sea level
South Carolina	3,548	Sea level
South Dakota	7,242	962
Tennessee	6,636	182
Texas	9,020	Sea level
Utah	13,498	2,000
Vermont	4,364	95
Virginia	5,719	Sea level
Washington	14,408	Sea level
West Virginia	4,860	240
Wisconsin	1,940	582
Wyoming	13,785	3,100

fects of these variables is not likely to exceed a 25 per cent range.

5. Standard apparatus applied at different locations in the range of elevations up to 3,300 feet will vary in flashover over a possible range of 35 per cent.

6. For many applications standard apparatus of the next higher voltage class fits the mean flashover range of the location.

7. For other cases it is necessary to use special apparatus or to gap equipment of excessively high rating to meet the average flashover requirements for the conditions encountered at a given location.

8. The desire to maintain flashover values and to avoid overstressing internal insulation prescribes permitting wide departures from basic insulation levels due to conditions of application.

9. This survey would seem to show greater variations in flashover voltages due to changing weather conditions in service than is generally realized. Although the situation is not to be regarded as alarming, it is well to keep it in mind. A full appreciation of the facts in a particular case should lead to a more effective application of apparatus to meet the conditions. On the other hand, certain applications which may have proved unsatisfactory might be explained by these simple natural phenomena. In addition, standardizing groups often find it necessary to consider information of this nature in formulating and revising standards.

References

1. Effect of Altitude on the Sparkover Voltages of Bushings, Leads, and Insulators, **F. W. Peek, Jr.** AIEE Transactions, volume 33, 1914, page 923.

2. La Tension de Contournement, Sous Ondes de Choc de Differentes Durees, des Isolateurs Salis et Sous Pluie, **W. Wanger.** CIGRE, Paris, 1939.

3. Proposed Standards for Outdoor Bushings, AIEE Transactions, volume 59, 1940 (October section), pages 590–1.

4. Temperature Survey of the United States, **J. J. Smith and H. W. Tenney.** AIEE Transactions, volume 59, 1940, pages 769–75.

5. Recommendations for High-Voltage Testing, AIEE Transactions, volume 59, 1940 (October section), pages 598–602.

6. Reference Values for Temperature, Pressure, and Humidity, **P. L. Beliaschi and P. H. McAuley.** AIEE Transactions, volume 59, 1940 (December section), pages 669–75.

7. The Elements of Hydrology, a book, **Adolph F. Meyer.** John Wiley and Sons, Inc.

Appendix

Altitude Corrections

The effect of altitude on apparatus rating is given in at least four different forms in the AIEE and ASA standards. Altitude affects voltage rating (flashover through air), cooling (air density) and losses (windage). More uniformity of terminology and method of specification appears possible and desirable.

In Standard No. 19 correction factors for voltage rating are given in the form of a table as given in section IX of this paper. The table values correspond exactly to one per cent reduction for each 330 feet above 3,300-feet altitude. In the same standard the correction for temperature rise is given as 0.4 per cent reduction for each 330 feet above 3,300 feet at which the actual installation is to take place.

In ASA Standard *C*-50 for rotating electrical machinery, the probable decrease in

Table III. Effect of Extreme Air Conditions on Flashover Corrections

Location	Boston, Mass.	Bismarck, N. Dak.	Great Falls, Mont.	Denver, Colo.	Cheyenne, Wyo.
Elevation—feet	Sea level	1,690	3,200	5,292	6,088
Barometer—inches	29.92	28.2	26.6	24.6	24.0
Highest temperature recorded	104	107	105	105	100
Corresponding relative air density	0.952	0.886	0.843	0.782	0.769
Highest dry bulb*	96	111	98		
Corresponding wet bulb	75	70	61		
Corresponding absolute humidity	0.64	0.278	0.2**	0.2	0.2**
Humidity correction	0.993	1.081	1.101	1.101	1.101
Flashover reduced to	0.958	0.819	0.765	0.710	0.698
Altitude rating standards number 19	100	100	100	94	91.6
Lowest temp. recorded	−18	−45**	−49	−29	−38
Corresponding relative air density	1.216	1.22	1.162	1.025	1.021
Humidity correction	1.12**	1.12**	1.12**	1.12**	1.12**
Flashover reduced to	1.085	1.089	1.038	0.915	0.912
Range in per cent	12.7	27.0	27.3	20.5	21.4

*At noon during July and August in a six-year period.

**Estimated.

Volt-Time Areas of Impulse Spark-Over

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ASSOCIATE AIEE

Synopsis: On the basis of classification of impulse wave shape, the paper shows that impulse spark-over characteristics of electrodes with nonuniform fields cannot be represented by single volt-time curves but must be represented by volt-time areas of considerable extent. This classification explains the large difference obtained by various laboratories when investigating sparkover between one and five microseconds. The effect of impulse generator discharge circuits in producing these differences is explained. The necessity of insulation co-ordination on the basis of volt-time areas is pointed out.

Introduction

EVER since it was definitely established that lightning strokes contribute the greatest amount of insulator flashovers on transmission lines as well as damage to important equipment such as transformers and circuit breakers, the problem of insulation co-ordination on the basis of impulse sparkover has become of great concern to the operating engineer, not only as a means of eliminating damage, but also of preventing flashovers causing system outages. Many papers[1] have been written on the large problem of co-ordination.

Co-ordination has been defined in various ways. One of the more recent definitions[2] is as follows:

'Insulation co-ordination may be defined as the process of setting standards of insulation strength and assigning them to all the items of equipment in the various insulation classes in such a manner as to produce, from an economic and operating standpoint, both a maximum of protection, and, if failure results, a minimum damage to the system."

From this definition it is apparent that the impulse strength of all types of apparatus comprising a transmission system has to be known, within fairly accurate limits, before co-ordination can be applied effectively. Consequent studies of the impulse flashover characteristics of suspension insulators, apparatus insulators, bushings as well as transformer insulation revealed that the impulse flashover in air, oil, or breakdown of solid insulation is not a constant value, but varies with time. Therefore, impulse strength of a given electrode arrangement and dielectric can be represented by a volt-time curve which correlates the spark-over voltage with the time at which the insulator will spark over.

Present Concept of Impulse Spark-Over Characteristics

In figure 1 a series of such volt-time curves are shown for different types of electrodes. The curves are plotted as overvoltage-time curves to show the relative increase of spark-over voltage as affected by the electrode arrangement. Overvoltage is the actual spark-over voltage expressed in per cent of the critical* spark-over voltage of the apparatus.

It is evident from a study of these curves that co-ordination on the basis of the critical spark-over voltage of different types of apparatus only cannot be effective, but that co-ordination must be based on the volt-time impulse characteristics of the apparatus. While the various laboratories in the United States of America conducting high-voltage research did agree within fairly close limits on the critical spark-over voltages of rod gaps and insulators,[3] considerable differences in results were obtained for volt-time spark-over curves.[4,5] For instance, the differences in measured spark-over voltages for rod gaps were found to be as great as 20 to 40 per cent at times to sparkover of two microseconds and less. These large differences were at first attributed to measuring methods such as the type of divider—resistance divider, shielded and unshielded, and capacitance divider—as well as insufficient precaution in the oscillograph technique. However, it was soon discovered that the shape of the applied impulse wave before spark-over occurs has a distinct bearing on the spark-over voltage of different types of apparatus.[6] The effect of wave shape,

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The author wishes to acknowledge the assistance of A. F. Rohlfs in the preparation of the paper and of G. G. Poulsen and J. W. Albright in obtaining the test data.

1. For all numbered references, see list at end of paper.

*The critical spark-over voltage of a test specimen under an impulse of any given wave shape and polarity is the crest value of that impulse when its amplitude is adjusted to cause flashover on 50 per cent of the applications.

---

ambient temperature at higher altitudes is recognized and applications at normal rating approved if the operating conditions are within the limits given in the following table.

Altitude		Maximum Temperature of the Cooling Air in Degrees Centigrade
In Feet	In Meters	
0– 3,300	0–1,000	40
3,300– 6,600	1,000–2,000	35
6,600– 9,900	2,000–3,000	30
9,900–13,200	3,000–4,000	25

In this case the percentage change varies with the different values of temperature rise since corrections are given in degrees of temperature.

In standard *C*-50 also, a correction of one per cent per 330 feet above 3,300 feet is specified for temperature-rise tests at low altitude on apparatus destined for use at altitudes above 3,300 feet.

ASA standard *C*-57 for transformers, regulators, and reactors gives corrections for temperature rise in per cent per 330 feet above 3,300 feet. Rates from 0.4 to 1 per cent are given depending on whether cooling is largely by radiation or conduction.

AIEE Standard No. 4 for voltage measurement gives a correction for spark-over voltages in air which includes both temperature and pressure (altitude) factors. Measured voltage values are divided by the relative air density to correct to standard conditions.

$$\text{relative air density} = \frac{0.392B}{273+T}$$

where

T = temperature degrees centigrade
B = pressure in millimeters of mercury

ASA standard *C*-50 gives a correction formula for windage losses for different temperature and pressure (altitude) conditions. The losses measured at a given temperature and pressure are multiplied by the factor $690\ \frac{(1+0.004T)}{B}$, in which T = temperature degrees centigrade and B = pressure in millimeters of mercury. Both this and the relative air density formula are unity at 25-degrees-centigrade and 760-millimeter pressure and one is the reciprocal of the other for practical purposes.

The International Electrotechnical Commission proposed specification for a-c circuit breakers (May 1938) states that the limits of temperature rise shall be reduced one per cent for each 300 meters (990 feet) above sea level at which the breaker is intended to work in service. The correction is not applied below 1,000 meters. In this case both the rate and the starting point of the correction are different from American Standards.

however, could not be classified, and, therefore, useful engineering data could not be supplied. Owing to the differences obtained by various laboratories, the volt-time curves were assigned plus and minus corrections of arbitrary value to account for what was thought to be erratic spark-over characteristic of certain types of apparatus.

New Concept of Impulse Spark-Over Characteristics

It will be left to the physicist to translate the following data into electrons, ions, and terms of photo-ionization. This paper will attempt to present the data in terms which the engineer interested in co-ordination and, therefore, in impulse spark-over characteristics of different kinds of apparatus, can use to apply to his problems.

The effect of wave shape is well illustrated by figure 2 which shows a series of volt-time curves and spark-over points for a 20-inch rod gap at negative polarity. Each of these curves was obtained with a constant impulse generator discharge circuit. For the lower curve the impulse wave had a front of 0.5 microseconds, for the middle curve a front of 2.4 microseconds and for the upper curve, 9.6 microseconds at the critical spark-over potential. It can be seen that the spark-over voltages associated with a given time to sparkover vary greatly with the shape of the wave front. For instance, at two microseconds the spark-over voltages for the two extreme wave fronts used are 495 kv and 625 kv respectively with a difference of 25 per cent. If, at the same time to sparkover, widely differing voltage values are obtained, gap spark-over has to be classified as either very erratic or the difference must be due to

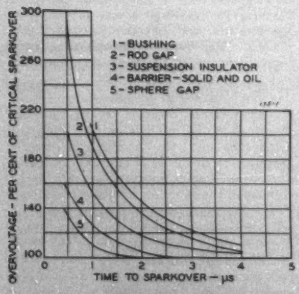

1 - BUSHING
2 - ROD GAP
3 - SUSPENSION INSULATOR
4 - BARRIER - SOLID AND OIL
5 - SPHERE GAP
OVERVOLTAGE - PER CENT OF CRITICAL SPARKOVER
TIME TO SPARKOVER - μs

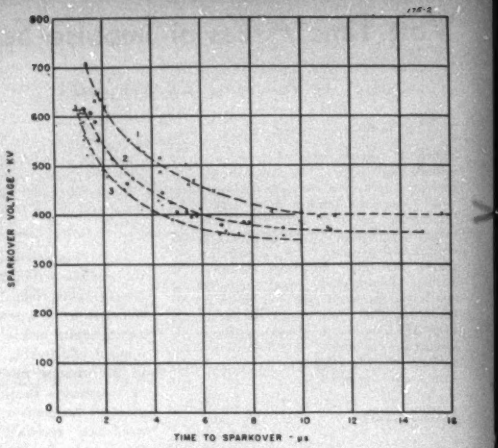
Figure 1. Comparison of overvoltage characteristics of different types of gaps

Negative polarity

Figure 2. Effect of wave front on spark-over volt-time curves for a 20-inch rod gap

Negative polarity. Vapor pressure 0.26 inch mercury; air density 0.983

Impulse circuit adjusted for: 1—9.6-microsecond wave front, 2—2.4-microsecond wave front, 3—0.5-microsecond wave front



some physical characteristics of the spark-over phenomenon. If spark-over voltages at two microseconds of 495 kv and 625 kv of a 20-inch rod gap had been obtained in isolated tests and not in the course of obtaining volt-time curves, the spark-over characteristic of the gap would indeed appear erratic.

However, since the results shown in figure 2 were obtained with impulse waves of different shapes, it is logical to attribute the difference to wave shape. Since the front of the wave definitely appears to have considerable influence on the variations in spark-over voltage, but, on the other hand, the front of the wave does not stay constant when sparkover occurs between two and ten microseconds, it was decided that the effective front might be used to derive a practical answer for classification of impulse wave shape. The effective front is specified by the slope of the line through the $0.3E$ and $0.9E$ points on the front, where E is the crest of the measured wave. The effective front in microseconds T_1 is the time between the $0.3E$ and $0.9E$ points multiplied by 1.66. For the tests with the slow front, this definition of effective front did not permit sufficient differentiation. Since slow fronts in all cases were of the exponential form, the initial rate of rise was used as the effective front. The time to sparkover T_2 in microseconds is the time from virtual zero time to a point on the wave where voltage is rapidly decreasing toward zero. Virtual zero time is defined as the intersection of the line through the $0.3E$ and $0.9E$ points with the zero line.

The same test points as shown in figure 2 were then replotted as function of kilovolt spark-over and the ratio of T_1/T_2 = (effective front)/(time to sparkover) with time to sparkover T_2 as parameter. Such a plot shows a scattering of points, indicating the trend of lower spark-over voltage for small ratios of T_1/T_2 and higher spark-over voltages for large ratios of T_1/T_2 for equal times to spark-over. In figure 3 the test points were plotted to show the range over which data have been obtained, but the time to

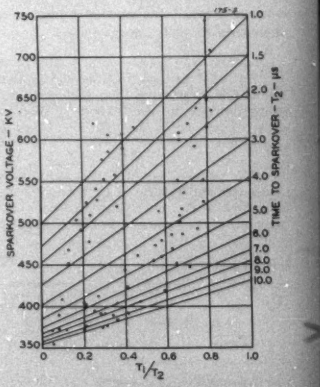


Figure 3. Effect of wave shape on spark-over voltage of 20-inch rod gap

Negative polarity. Vapor pressure 0.26 inch mercury; air density 0.983

T_1 = effective wave front, T_2 = time to spark-over

Test points indicate range investigated

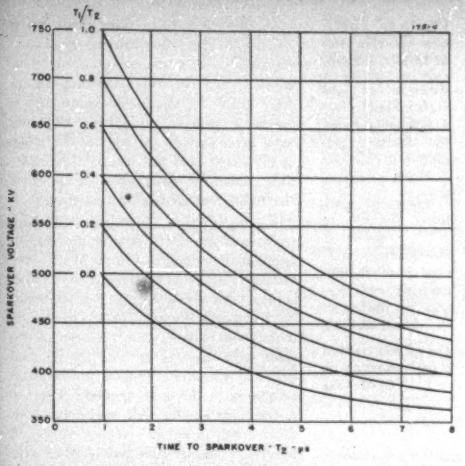


Figure 4. Spark-over volt-time area of 20-inch rod gap

Boundaries are $T_1/T_2=0$ and $T_1/T_2=1$. Negative polarity. Vapor pressure 0.26 inch mercury; air density 0.983

T_1 = effective wave front; T_2 = time to spark-over

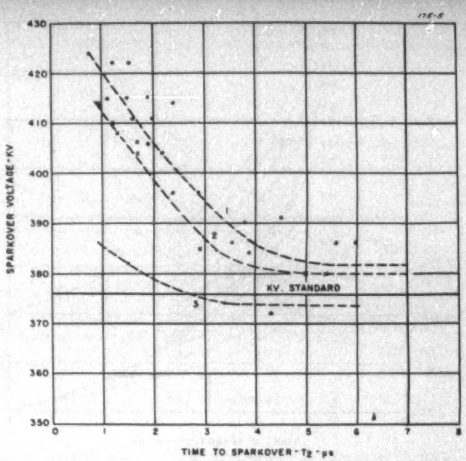


Figure 5. Spark-over volt-time curves of 50-centimeter spheres spaced 15.5 centimeters

Negative polarity. Air density 1

Impulse circuit adjusted for: 1—9.6-microsecond wave front, 2—2.4-microsecond wave front, 3—0.5-microsecond wave front

sparkover associated with each test point was omitted for reasons of reproduction. The network of straight lines, indicating spark-over voltage trends for a given time to sparkover, has been placed such that it most nearly represents the correct interpretation of the test results.

The lower limit $T_1/T_2=0$ and the upper limit $T_1/T_2=1$ have not been reached during these tests. The lower limit, of course, represents a wave with abrupt rising front and practically rectangular tail, while the upper limit represents a front rising in a straight line from the zero point to the spark-over point. Both of these limits are difficult to obtain in practical impulse testing. However, the error in extending the straight lines to both of these limits beyond the available test points should not result in appreciable errors.

To reduce the results to the customary form of the volt-time curves, the straight lines of figure 3 have been used to draw the curves of figure 4, where spark-over voltage in kilovolts is plotted as function of time to sparkover with the ratio T_1/T_2 as parameter.

This figure shows clearly that spark-over of a rod gap for instance cannot be represented by a single "volt-time curve" but rather by a "volt-time area." This volt-time area, in contrast to previous attempts of using correcting factors in connection with volt-time curves, is well defined by recognition of the influence of impulse wave shape on spark-over voltage. It will be shown that the use of the wave shape definition adopted gives results within a few per cent of expected spark-over voltages. Therefore, the use of volt-time areas will eliminate to a large extent the uncertainty heretofore associated with short-time sparkover of insulators, bushings, rod gaps, and other apparatus. It is important to note that this spark-over area, of course, is subject to the variations in spark-over voltage due to humidity and air density. The correct method of correcting for humidity throughout this spark-over area is not known. If the method at present used for volt-time curves is adopted[7] it means that at short times to sparkover the spark-over values will remain practically the same while at the longer times the spark-over voltages will be raised, so that the individual volt-time curves for different T_1/T_2=constant will have a reduced slope at the longer times to sparkover, and the total spark-over area will be reduced when based on standard conditions of humidity. The air density correction probably will be the same regardless of wave shape.

It has been shown that the impulse spark-over voltage (e) of an electrode arrangement producing a nonuniform field, such as the rod gap, is a function not only of the time at which sparkover occurs, but also of wave shape represented by the ratio of T_1/T_2. Therefore $e=f(T_2, T_1/T_2)$. The physical condition for this dependence of spark-over voltage on wave shape is primarily the fact that corona currents of considerable amplitude have to flow through the dielectric to obtain sufficient ionization before sparkover can be completed.[8] The amplitude of these corona currents in turn depends on the voltage applied to the gap and the length of time voltage has been applied to the electrodes. Obviously wave shape cannot accurately be described by a ratio of T_1/T_2, especially for waves with unusual shapes, but in the range below six microseconds the results obtained indicate a sufficient consistency to justify the use of this approximation until more exact methods are available.

Volt-Time Areas of Different Types of Electrodes

The Quasi-Uniform Field

From the foregoing discussion it should be expected that spark-over voltage of electrode arrangements producing a uniform field should be represented by straight lines parallel to the zero axis (each spacing between electrodes represented by one line) and without the tendency of spark-over areas because heavy corona currents are not required to initiate sparkover. The closest approximation to the uniform field available for testing at higher voltages is the sphere gap at spacings small with respect to the diame-

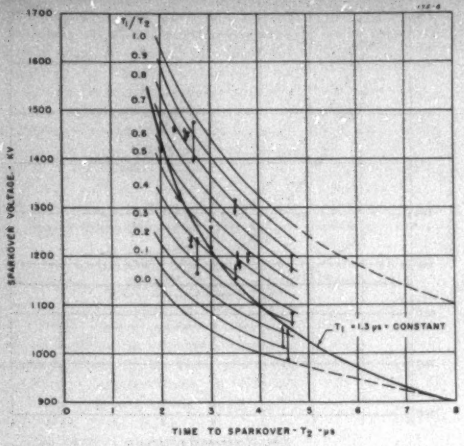


Figure 6. Spark-over volt-time area of 50-inch rod gap

Boundaries are $T_1/T_2 = 0$ and $T_1/T_2 = 1$. Negative polarity. Standard conditions of humidity and air density

T_1 = effective wave front; T_2 = time to spark-over

Points indicate measured values. Arrows point to correct location of test point based on T_1/T_2

T_1 = 1.3-microsecond curve from tests with 1.5x40 wave

ter of the sphere. The same types of waves used for the rod gap were applied to a 50-centimeter sphere gap spaced 15.5 centimeters. This spacing was chosen because it required a spark-over voltage approximately equal to the critical spark-over of the 20-inch rod gap.

The results of these tests are shown in figure 5. This figure shows in a greatly enlarged scale the test points and the probable volt-time curves for the three test conditions as outlined for the 20-inch rod gap. Only two test points were obtained for the short front-long tail wave. The differences between the two slow front waves are insignificant. At one microsecond the difference between minimum and maximum measured voltages is only nine per cent. Since the probable measuring error is of the order of three per cent, it can be said that the volt-time area of a sphere gap, representing a nearly uniform field is extremely small as compared to that of a rod gap at times to sparkover of one microsecond and greater. The data do not permit drawing of T_1/T_2 = constant curves as shown for the 20-inch rod gap in figure 4.

The Nonuniform Field

In addition to the 20-inch rod gap at negative polarity, volt-time areas have been obtained for the 50-inch rod gap at negative polarity, figure 6, and the 20-inch rod gap at positive polarity, figure 7. In the latter two figures the test points have been superimposed on the plot of the T_1/T_2 = constant curves as follows: The spark-over potentials in kilovolts as function of time to sparkover are represented by the solid points. From these test points an arrow is drawn to the expected location of the point according to the ratio T_1/T_2 of the wave. It is apparent that the test points check the expected values very closely. In figure 6 is also shown a conventional volt-time curve for the 50-inch rod gap taken with a 1.5x40 wave. It is evident that such a curve cannot represent the spark-over characteristics of the rod gap. Data of figure 6 and figure 7 have been corrected to standard conditions of humidity and air density according to accepted methods.[7]

Further tests have been made on a string of three suspension insulators (figure 8), a stack of two apparatus insulators (figure 9), and a bushing (figure 10). Only the T_1/T_2 = constant curves for these different insulating elements have been plotted to indicate the slope of the curves and the extent of the volt-time areas for comparison with the other electrode arrangements investigated.

A comparison of the volt-time characteristics of the electrode arrangements of approximately equal critical spark-over voltages shows that the slope of the T_1/T_2 = constant curves is steepest for the bushing, rod gap, line and apparatus insulators in the order named, while the extent of the spark-over areas is greatest for the rod gap, line insulators, bushing and pedestal insulators in the order named. This sequence corresponds well to the trend indicated by the single volt-time curves of figure 1. The electrode arrangement with the least overvoltage—the sphere gap—has the smallest volt-time area, while the higher overvoltages at a given time to sparkover of the single volt-time curve are indicative of larger volt-time areas.

The effect of wave shape on breakdown characteristics of barriers (representing major insulation of oil-filled transformers)—represented by overvoltage-time curve 4, figure 1—has not been investigated. Judging from this volt-time characteristic, the volt-time breakdown area of such a barrier should be intermediate between the spark-over areas of the sphere

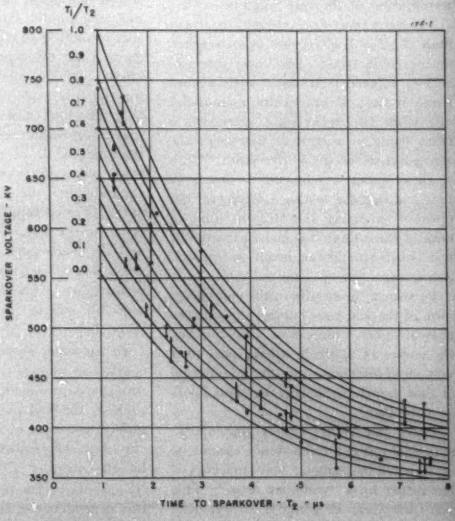


Figure 7. Spark-over volt-time area of 20-inch rod gap

Boundaries are $T_1/T_2 = 0$ and $T_1/T_2 = 1$. Positive polarity. Standard conditions of humidity and air density

T_1 = effective wave front; T_2 = time to spark-over

Points indicate measured values. Arrows point to correct location of test point based on T_1/T_2

gap and the line insulators, depending greatly on the type of electrodes and the field between them. Further tests are needed to obtain data comparable to those represented in the paper for air dielectrics.

It has been customary[9,10] to represent rod gap spark-over voltages as function of rod gap spacing with the time to spark-over as parameter; similarly, insulator sparkover is represented as function of number of insulators or string arc-over distance. Such curves were based on single volt-time curves taken at various spacings using a standard 1.5x40 wave. On the basis of spark-over volt-time areas, such curves should be drawn for each T_1/T_2=constant curve, or, since the limiting conditions are of greatest importance, for the two conditions $T_1/T_2=0$ and $T_1/T_2=1$.

The results of the tests presented here permit the plot of such curves for the rod gap between 20-inch and 50-inch spacing at negative polarity (figure 11). To conserve space, curves for the two extremes have been plotted on the same figure and, to avoid overlapping of the extreme ranges, the curves shown range only between two microseconds and four microseconds to sparkover. In addition, typical curves as obtained with the 1.5x40 wave are included.

Effect of Impulse Generator Circuits on Spark-Over Voltage

It is interesting to note that the solid two-microsecond curve as obtained from tests with a 1.5x40 wave (figure 11) is a curve rather than a straight line. This means, of course, that the wave shape at two microseconds to sparkover of the 20-inch rod gap was different from the wave shape during tests on the 50-inch rod gap, although the wave shape at the longer times to sparkover was practically the same in both tests as indicated by the straight lines for three microseconds and four microseconds.

This difference in wave shape at the short times to sparkover is due to the effect of the corona currents required for ionization of the gap to complete spark-over and the resulting voltage drop in the series impedance—inductance and resistance—of the impulse generator discharge circuit. The resulting change of the wave shapes is shown in figure 12. On this figure the wave shape at two microseconds to sparkover is compared with the wave shape at critical sparkover for two types of impulse generator discharge circuits. In figure 12*a* the wave shape is controlled by a series resistance and a small load capacitance which principally

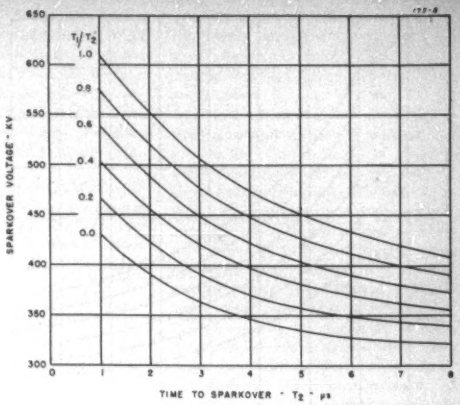


Figure 8. Spark-over volt-time area of a three-unit string of suspension insulators

Boundaries are $T_1/T_2=0$ and $T_1/T_2=1$. Negative polarity. Vapor pressure 0.26 inch mercury; air density 0.983

T_1 = effective wave front; T_2 = time to spark-over

consists of the inherent capacitance of the impulse generator plus a small additional load capacitance, a total of approximately 300 micromicrofarads. In order to obtain a 1.5-microsecond front with such a small capacitance, it is necessary to use a series resistance of 1,700 ohms. The corona currents through the gap have an amplitude of the order of hundreds of amperes and, therefore, the voltage drop through the resistor is several hundred thousands of volts. This voltage drop subtracts from the wave as it would have appeared, if the corona currents had not flown through the gap. The effective wave front is, therefore, changed from a 1.2-microsecond front at critical sparkover to 0.6 microsecond at 2 microseconds to sparkover. Therefore, the ratio of T_1/T_2 for this wave at two microseconds is $0.6/2=0.3$ which results in a spark-over voltage of 534 kv from figure 4 when corrected for air conditions. This checks the value of 535 kv obtained from figure 11.

In the other circuit, figure 12*b*, the load capacitance is concentrated close to the rod gap and has a value of 800 micromicrofarads. The series resistance is 800 ohms giving a front of 1.8 microseconds and an effective front of 1.3 microseconds. For equal amounts of corona currents, as for the circuit 12*a*, the voltage drop across the resistor due to the corona is considerably reduced because it can be supplied by the capacitor direct without any appreciable voltage drop. Consequently, the effective front is not changed and at two microseconds to sparkover the ratio $T_1/T_2=1.3/2=0.65$. From figure 4 a spark-over voltage of 587 kv results, which, when corrected to standard conditions of humidity and air density, gives 610 kv as compared to 534 kv obtained with impulse generator circuit of figure 12*a*. This spark-over voltage of 610 kv was actually obtained during tests on the 20-inch rod gap with circuit of figure 12*b* in the process of obtaining a volt-time curve before and independent of this present investigation. Data of figure 4 have been obtained recently. It is, therefore, significant to the value of this proposed classification of impulse wave shapes in terms of T_1/T_2 that test data on the same type of gap taken several years ago should check so well when analyzed on the basis of that ratio.

The solid curves shown in figure 11 were obtained with an impulse generator connected as in figure 12*a* for the 20-inch and 30-inch gap, while the tests for the 50-inch gap were made with circuit of figure 12*b*. If the value of 610 kv for the 20-inch rod gap is plotted on figure 11, a straight line for the two-microsecond test curve results.

These examples show that

1. Differences in spark-over voltages obtained on electrode arrangements with non-uniform field are directly due to differences in impulse generator discharge circuits.

2. Spark-over voltages, when classified according to wave shape as expressed by the ratio of effective front to time to sparkover, are consistent on the basis of spark-over volt-time areas, although they appear erratic on the basis of volt-time curves.

3. The effective wave front produced by some types of impulse generator discharge circuits during investigations of impulse volt-time curves of apparatus with non-uniform field varies considerably throughout the range of times to sparkover from critical to one to two microseconds. Such generators produce volt-time curves where neither T_1=constant nor T_1/T_2=constant. The change in effective front depends on the type of apparatus tested, whether large or

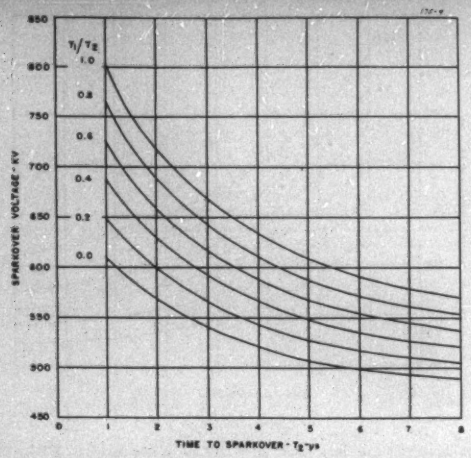


Figure 9. Spark-over volt-time area of a two-unit stack of apparatus insulators

Boundaries are $T_1/T_2=0$ and $T_1/T_2=1$. Negative polarity. Vapor pressure 0.26 inch mercury; air density 0.983

T_1 = effective wave front; T_2 = time to spark-over

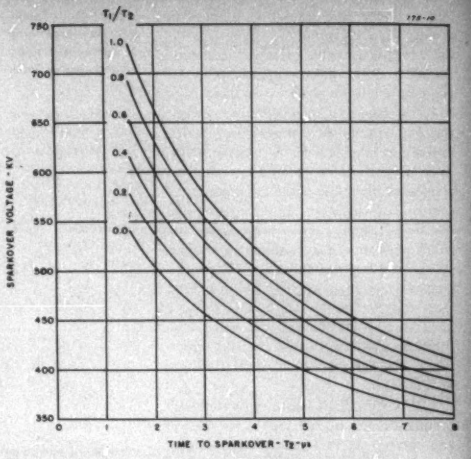


Figure 10. Spark-over volt-time area of a bushing

Boundaries are $T_1/T_2=0$ and $T_1/T_2=1$. Negative polarity. Vapor pressure 0.26 inch mercury; air density 0.983

T_1 = effective wave front; T_2 = time to spark-over

small corona currents are required to complete sparkover.

4. The effective wave front produced by the other type of generator is constant throughout the same range of time to sparkover. Therefore, the volt-time curve produced has a constant T_1. Wave shape at any given time to sparkover is practically independent of the type of apparatus tested. It is, therefore, clear that for purposes of comparison of volt-time curves of apparatus with great differences in electric field distribution, tests made with an impulse generator discharge circuit of the type shown in figure 12*b* are directly comparable. Similar tests made with a generator of the type shown in figure 12*a*, however, are not directly comparable and have to be interpreted with considerable care. Until volt-time areas of all types of insulation structures are available, the effective fronts obtained during tests on volt-time curves should be recorded throughout the range investigated, since they have such a profound effect on the values of spark-over voltages obtained.

Effect of Volt-Time Areas on Co-ordination

The data are obtained on too few types of apparatus to enable complete understanding of all the requirements for effective co-ordination. However, sufficient data are presented to make general recommendations. For this purpose the term co-ordination is used in a restricted sense, such that "co-ordination between two apparatus is obtained if the impulse strength of one of them is below the other, so that sparkover always occurs on the apparatus with lower strength." On the basis of volt-time curves this means that the volt-time curve of apparatus *A* is lower than that of apparatus *B* throughout the expected spark-over time range.

As shown by the examples of the sphere gap and the insulators, quasi-uniform fields between electrodes are associated with small impulse spark-over areas, while the nonuniform field is associated with large impulse spark-over areas. The problems of co-ordinating voltage levels for the large variety of electrode fields encountered in electrical apparatus, therefore, consists in co-ordinating according to spark-over areas rather than according to single volt-time curves. This, of course, complicates the co-ordinating problem to a certain extent.

However, the problem can be reduced to three fundamental conditions (figure 13):

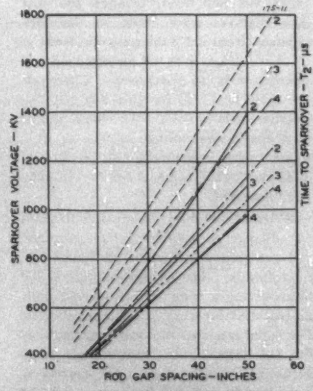


Figure 11. Impulse spark-over characteristics of rod gaps

Negative polarity. Standard conditions of humidity and air density

Solid lines—tests with 1.5x40 wave
Dashed lines—$T_1/T_2=1$ curves
Dot-dash lines—$T_1/T_2=0$ curves

T_1 = effective wave front; T_2 = time to spark-over

(*a*). Apparatus with the lower impulse strength (*A*) has a narrow band spark-over area; apparatus with the higher impulse strength (*B*) has a wide band spark-over area (for instance, a sphere gap (*A*) and insulator string (*B*)).

In this case co-ordination can be made effective if the $T_1/T_2=0$ spark-over curve of (*A*) is below the $T_1/T_2=0$ spark-over curve of (*B*) because regardless of wave shape, the impulse strength of (*A*) will be exceeded before that of (*B*) is reached.

(*b*). Apparatus with the lower impulse strength (*A*) has a wide band spark-over area; apparatus with the higher impulse strength (*B*) has a narrow band spark-over area. In this case, co-ordination can be made effective if the $T_1/T_2=1$ spark-over curve of (*A*) is below the $T_1/T_2=1$ spark-over curve of (*B*).

(*c*). Regardless of the band of the spark-over areas of both apparatus co-ordination is effected if the $T_1/T_2=1$ spark-over curve of (*A*) is below $T_1/T_2=0$ spark-over curve of (*B*).

Condition (*c*), of course, is the most satisfactory method of assuring that apparatus with the lower impulse strength will reduce the impulse voltage before the impulse strength of (*B*) is reached. However, under conditions where the margin between apparatus (*A*) and (*B*) can be kept to a minimum, matching of the spark-over areas as indicated in figure 13, (*a*) and (*b*) should give considerable improvement as compared to a consideration of single volt-time curves only. It is obvious that apparatus with nonuniform field and consequent wide band spark-over areas are not suited to limit impulse spark-over voltages in stations where costly equipment may be damaged if the limiting level of the apparatus is set too high. If, on the other hand, the limiting level is set sufficiently low, following condition of figure 13*c*, the spark-over characteristics will be such that switching surges and other low and medium system disturbances will result in a large number of system outages.

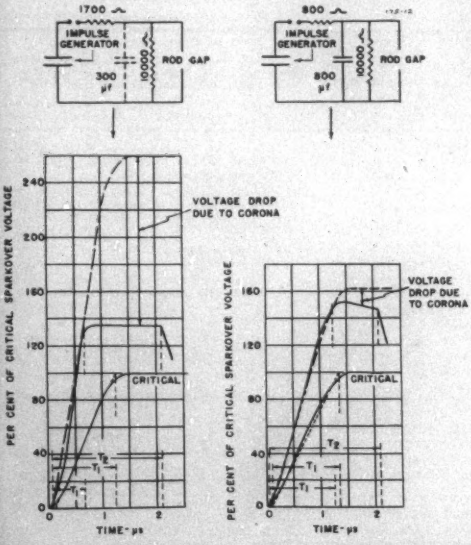


Figure 12. Effect of impulse generator discharge circuits on effective wave front—T_1

Wave Shape Variations on Transmission Lines

The question naturally arises whether apparatus in service will be subjected to waves of such a great variety of shapes as to warrant the investigation of impulse sparkover of areas as has been done in this paper for a few types. The available data are limited, due to the very costly nature of investigations of wave shapes of natural lightning on transmission lines, but approximate limits can be given.

Lewis and Foust[11] give a summary of a study of natural lightning on transmission lines in the United States of America which shows that wave fronts may vary between 1 microsecond and 80 microseconds wave tails between 4 and 160 microseconds. Berger[12] in Switzerland recorded wave fronts up to 80 microseconds causing flashover of insulation at a terminal station. From these limited measurements of traveling waves on actual transmission systems, the possibility of great variations in wave fronts and wave shapes is indicated. Therefore, the large variations in spark-over voltages, as shown to exist for electrode arrangements with nonuniform field, are a distinct possibility and should be taken into account in the co-ordination problem.

Conclusions

1. Impulse spark-over voltages of electrode arrangements with nonuniform field—such as insulators, bushings, rod gaps—cannot be represented with sufficient accuracy by volt-time curves, but must be represented by volt-time areas.

2. The extent of these areas may be considerable. The spark-over voltage of a string of three suspension insulators for instance, ranges between 430 kv and 620 kv with sparkover taking place at one microsecond, a difference of 45 per cent, or at six microseconds to sparkover the spark-over voltage ranges between 330 kv and 430 kv, a difference of 30 per cent.

3. The great differences in voltages at any given time to sparkover are not due to erratic nature of sparkover, but due to differences in the shape of the applied impulse wave before sparkover occurs.

4. The experimental data show that differences in wave shape can be classified by the ratio of the effective front of the wave to the time to sparkover—T_1/T_2. $T_1/T_2=0$ represents a wave with very steep front and practically rectangular tail while $T_1/T_2=1$ represents a wave with a front rising in a straight line from zero time to the time of

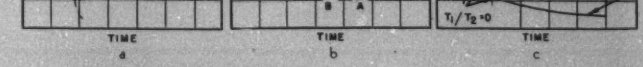


Figure 13. Co-ordination on basis of spark-over volt-time areas

A—Apparatus with lower spark-over strength
B—Apparatus with higher spark-over strength

a—*A* has narrow band spark-over area, *B* has wide band spark-over area
b—*A* has wide band spark-over area, *B* has narrow band spark-over area
c—Band width of spark-over area irrelevant

sparkover. Wave shapes where the ratio T_1/T_2 is small are associated with the lower spark-over voltages while straight line voltage rise produces the highest spark-over voltage at any given time to sparkover.

This means that the customary volt-time curves give only a very incomplete spark-over characteristic for any given electrode arrangement. The deviations from such curves are summarized in the following table (data from figure 6) for the 50-inch rod gap.

	Times to Spark-Over—Microseconds				
	2	3	4	5	6
Total spread of spark-over voltage in per cent of lower boundary	44	38	33	28	25
Per cent difference from typical volt-time curve with $T_1 = 1.3$ micro-seconds +	13	19	21	21	22
Per cent difference from typical volt-time curve with $T_1 = 1.3$ micro-seconds −	28	16	11	6	2

The maximum and minimum differences between the boundaries of the spark-over areas and volt-time curves depend on the impulse generator connection used for obtaining the curves.

5. The dependence of spark-over voltages on wave shape explains the great difference of spark-over voltage for a given electrode arrangement reported from different laboratories. The differences, in the range of one microsecond and more, are principally due to the difference in types of impulse generators used for the investigations. Although two impulse generators may produce the same wave shape at critical sparkover, at shorter times to sparkover (four microseconds and less) the wave shapes become radically different. One type produces a wave with a short effective front. Therefore, T_1/T_2 is small and the resulting spark-over voltage is low; the other produces a wave with a practically constant effective front. Therefore, T_1/T_2 is large and the resulting spark-over voltage is high.

Thus, this classification of wave shape is a satisfactory means for explaining the large voltage differences observed by various laboratories at times to sparkover of one microsecond or more.

6. The same phenomena which cause the upturn of spark-over volt-time curves are responsible for spark-over volt-time areas. Impulse sparkover in the nonuniform field requires corona currents of considerable amplitude to complete sparkover. The amplitude and the length of time of current flow determine the time to sparkover and the crest voltage of the wave causing spark-over. Therefore, for equal times to spark-over, a wave shape for which corona starting voltage is attained in a short time will require a lower spark-over voltage than a wave shape where corona starting voltage is attained later. Likewise, for equal spark-over voltages, early start of corona current will produce a shorter time to sparkover than a late start of corona currents.

7. Therefore, in the quasi-uniform field, such as the sphere gap, where corona currents are of small amplitude or negligible at times to sparkover of one microsecond or more, the effect of wave shape on the spark-over characteristic is very small, the upturn of the volt-time curves is negligible, and the extent of the spark-over area is negligible. At times shorter than one microsecond the effect of corona current becomes considerable and the sphere gap should exhibit increasing extent of spark-over area and upturn of voltage.

8. Methods of co-ordinating system insulation on the basis of impulse spark-over areas rather than volt-time curves are pointed out.

9. The data presented here are only another step to a more complete understanding of spark-over phenomena. The classification of impulse wave shape by means of a simple ratio of effective front to time to sparkover, while not based on a precise scientific interpretation of the phenomenon, nevertheless gives excellent practical results.

References

1a. The Co-ordination of Transformer Insulation With Line Insulation, **V. M. Montsinger and W. M. Dann.** AIEE Transactions, volume 51, 1932, pages 923–4.

1b. Co-ordination of Insulation, **V. M. Montsinger, W. L. Lloyd, Jr., and J. E. Clem.** AIEE Transactions, volume 52, 1933, pages 417–27.

1c. Insulation Co-ordination, **Philip Sporn and I. W. Gross.** AIEE Transactions, volume 56, 1937 (June section), pages 715–20.

2. Basic Impulse Insulation Levels, **Philip Sporn and C. A. Powel.** AIEE Transactions, volume 59, 1940 (October section), pages 596–8.

3. Flashover Characteristics of Rod Gaps and Insulators, AIEE Transactions, volume 56, 1937 (June section), pages 712–14.

4. Short-Time Sparkover of Gaps, **J. H. Hagenguth.** AIEE Transactions, volume 56, 1937 (January section), pages 67–76.

5. Impulse Voltages Chopped on Front, **P. L. Bellaschi.** AIEE Transactions, volume 55, 1936 (September section), pages 985–90.

6. Discussion on reference 4, **J. H. Hagenguth.** AIEE Transactions, volume 56, 1937 (July section), pages 885–7.

7. Recommendations for High-Voltage Testing, **EEI-NEMA Subcommittee Report.** AIEE Transactions, volume 59, 1940 (October section), pages 598–602.

8. Ionization Currents and the Breakdown of Insulation, **J. J. Torok and F. K. Fielder.** AIEE Transactions, volume 49, 1930, pages 352–7.

9. Impulse Voltage Strength of Insulators and Materials, **J. C. Dowell and C. M. Foust.** *General Electric Review*, March 1937.

10. Flashover Characteristics of Insulation, **P. H. McAuley.** *The Electric Journal*, July 1938.

11. Lightning Surges on Transmission Lines—Natural Lightning, **W. W. Lewis and C. M. Foust.** *General Electric Review*, November 1936, pages 543–55.

12. Resultate der Gewitter Messungen Inden Jahren, 1932–1933, **K. Berger.** *Bull. S.E.V.*, April 27, 1934.

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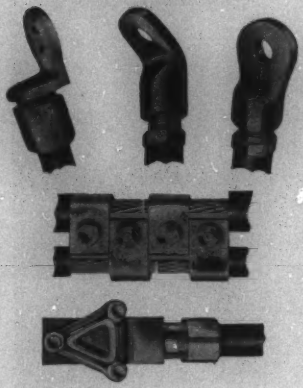

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Portable Substations.—Bulletin B-2281, 8 pp. Describes portable substations to meet a wide range of operating conditions and available in all voltage ratings up to 69 kv and in capacities up to 4,500 kva. Typical trailer mounted substations are illustrated and engineering details are explained. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Cable Terminators and Supports.—Bulletin 4101. Describes sealed type, single conductor cable terminators. Bulletin 4103. Describes type "VE" 3-conductor cable supports for triangular cable spacing in voltages up to 440. The Delta-Star Electric Co., 2400 Block, Fulton St., Chicago, Ill.

Motors.—Bulletin GEA-3580, 12 pp. Describes the "Tri-Clad" line of motors, features of which include one piece, cast-iron frame and end shield for protection against physical damage; the stator windings of Formex wire for protection against electrical breakdown; and the new design of bearings reducing operating wear and tear. General Electric Co., Schenectady, N. Y.

Pole Guying Specifications.—Folder, 4 pp. These simplified guying specifications are based on the properly coordinated use of the manufacturer's through-bolt guy hooks, eye nuts and curved washers, together with standard stock through-bolts and lags. Three ranges of capacity are covered, normal, heavy and very heavy guying. Equipment is listed with complete data for specifications and illustrations show applications of guying accessories to poles. Malleable Iron Fittings Co., Branford, Conn.

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Electrical Tape.—Cat. Sec. 9270, 4 pp. Describes "Two-In-One" tape which combines the functions of splicing compound and friction tape. The use of the tape in various services, as well as methods of application, are illustrated. The B. F. Goodrich Co., Akron, Ohio.

Arc Welding System.—Bulletin. Describes a new "Multiple Star" welding system and preheating and normalizing development. A typical system consists of twelve 600-ampere welding stations operating from one 3-phase transformer, located outside the plant, if desired. Simple controls enable each operator to regulate voltage and current. No-load power input is reduced to a minimum; when welding ceases, there are practically no power costs. Each unit draws only such power as is required to make a given weld. Increased welding speed and better welds are also claimed for the system. Electric Arc Cutting & Welding Co., 152 Jelliff Ave., Newark, N. J.

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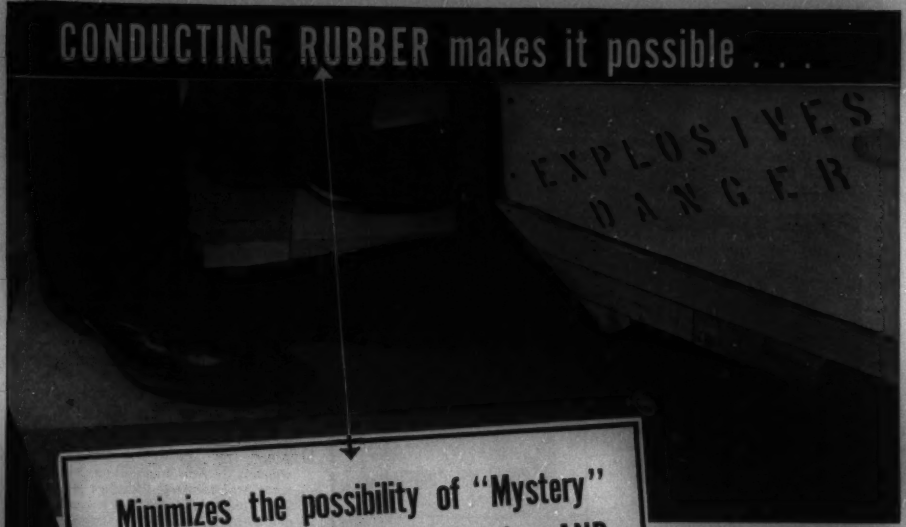

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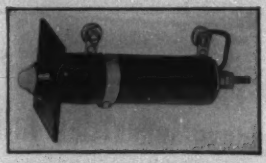
Power Relay.—A new sensitive relay, model BK25, has been introduced by the Kurman Electric Co., 241 Lafayette St., New York City. Voltmeter accuracy is from −24

to +99 degrees Centigrade. Moulded base; silver contacts; operates on .0018 watt. According to the manufacturer, vibration or temperature changes will not interfere with the relay's operation.

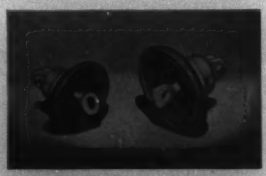
Resistors.—A new line of negative temperature coefficient resistors, several units of which are illustrated, has been announced by the Keystone Carbon Co., 1935 State St., St. Marys, Pa. The new resistor material is a hard, black, non-metallic substance, the chief characteristic of which is a decrease in electrical resistance with an increase in temperature. This property makes the material useful where it is desired to reduce or eliminate initial current surges, to secure a time delay or gradual building-up of the current through a piece of equipment, to provide temperature compensation in apparatus or equipment which exhibit rising resistance with increase in temperature, and for other applications where a negative temperature coefficient is required. The temperature of a resistor made of this material can be changed either externally by a change in ambient temperature, or internally by heat developed by passage of current through the resistor, or by a combination of both. Change of resistance with temperature change occurs in the region of ordinary temperatures, namely, 0–150° Centigrade.

Indicating Lamps.—The Allis-Chalmers Mfg. Co., Milwaukee, Wis., has developed an improved line of indicating lamps for visual or pilot light indication on switchboards, switchgear, panels and controls. Simple in construction, they require very little panel space for mounting. The use of special material in the color cap permits less lamp voltage with equal brilliance and corresponding longer lamp life, consuming only about 4 watts. The color caps are threaded and easily removed and replaced from the front of the board. The receptacle is made of insulating material and mounts from the front of the panel through a $^{3}/_{4}$-inch hole. The assembly mounts on any thickness of panel up to 2 inches, without panel



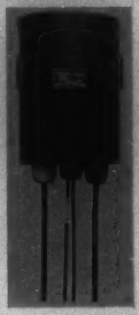
counterboring, and projects less than 5 inches from the face surface of the panel. Binding screws provide easy means for making connections. The lamp slips into the receptacle from the front after the color cap is unscrewed. The lamp bulb may be removed without the use of tongs, wrenches, pullers or other tools.

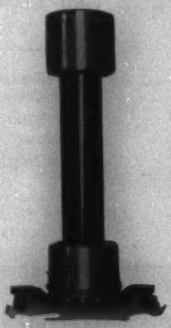
Breakage-Resistant Insulators.—To reduce breakage of suspension insulators on lower-voltage lines, the Ohio Brass Co., Mansfield, O., has developed three small-diameter units with a smooth under surface



and heavy porcelain sections. Being free of the deep petticoats located on the under side of standard suspension insulator discs, these units allow bullets to ricochet off the surface without causing damage in most cases. The greater impact resistance of the heavier-sectioned porcelain helps reduce breakage from rock throwing, falling objects, and rough handling during shipment and installation. Elimination of petticoats lowers the electrical flashover values only slightly. The three insulators include a 6-inch, 10,000-lb. unit with clevis cap and eye pin, and two $7^{1}/_{2}$-inch, 15,000 lb. units, one with socket cap and ball pin, and one with clevis cap and clevis pin.

Outdoor Potential Transformer.—A new outdoor potential transformer for 2,300 volts and below has been announced by the meter division of the General Electric Co., Schenectady, N. Y. Designated type JE-3, the new transformer is especially suitable for accurate metering service. It supersedes the type JE-36, but retains the same dimensions so that the two are interchangeable. Accuracy ratio and phase-angle characteristics also remain unchanged. Insulation of the JE-3 has been materially improved. In the 2,300/115-volt rating the new transformer's insulation is sufficient to meet the impulse test requirements of a 60-kv full wave which is the ASA standard for 5-kv instrument transformers. Ratings below 2,300 volts meet the impulse test requirements of a 50-kv full wave. Accuracy classification of the JE-3 is $^{1}/_{4}$W, $^{1}/_{4}$X, $^{1}/_{2}$Y. It is rated 200 volt-amperes and is compensated for correct ratio at 50 volt-amperes at unity power factor. It will carry 300 volt-amperes continuously on a thermal basis without overheating.





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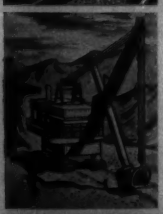

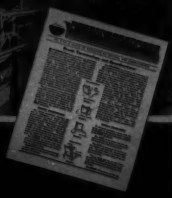

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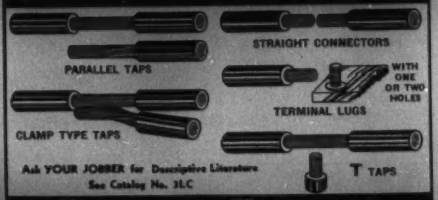

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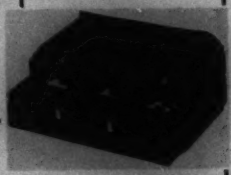

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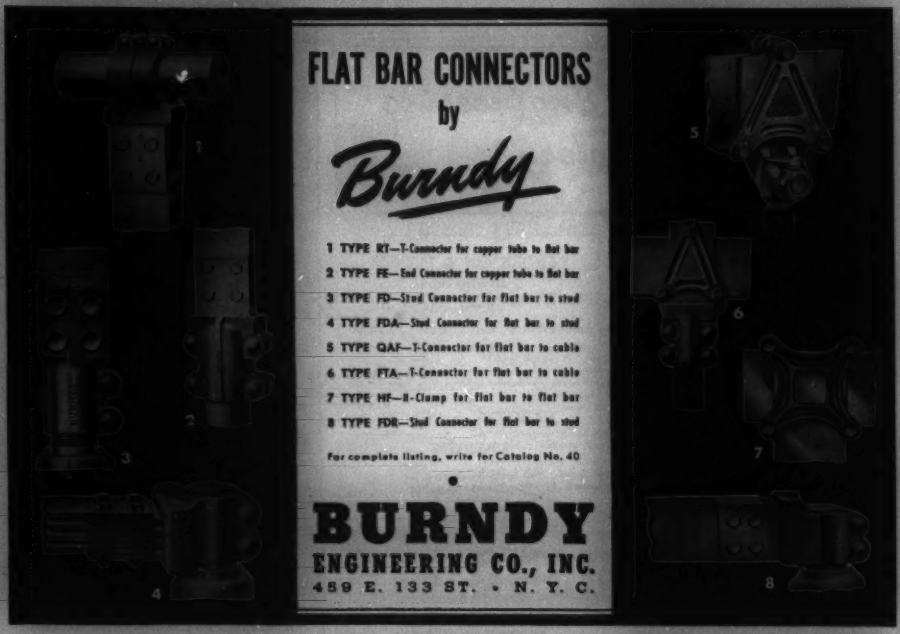
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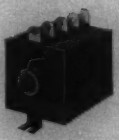

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Armstrong Cork Company	*
Behr, Leo	16
Belden Manufacturing Company	1
Benwood Linze Co., The	23
Biddle Company, James G.	18
Black & Veatch	24
Bull Dog Electric Products Co.	*
Burndy Engineering Company, Inc.	23
Carnegie-Illinois Steel Corporation	*
Chicago Transformer Corporation	5
Classified Advertisements	18
Columbia Electric Mfg. Company	25
Copperweld Steel Company	23
Corning Glass Works	10
Crescent Ins. Wire & Cable Co., Inc.	*
Dixon's Typhonite Eldorado Pencils	*
DuMont Laboratories, Inc., Allen B.	*
Eagle Pencil Company	*
Electrical Engineering	18
Electrical Testing Laboratories	24
Engineering Directory	24
Engg. Societies Personnel Service, Inc.	24
Engg. Societies Library	*
Ferranti Electric, Inc.	11
Fowle & Company, Frank F.	24
General Cable Corporation	8
General Electric Company	9, 2nd Cover
General Radio Company	2
Gibson Electric Company	*
Hazard Insulated Wire Works	3
International Resistance Company	4
International Telephone Dev. Co., Inc.	*
I-T-E Circuit Breaker Company	17
Irvington Varnish & Insulator Co.	20
Jackson & Moreland	24
Kerite Ins. Wire & Cable Co., Inc., The	13
Kuhlman Electric Company	3rd Cover
Krueger & Hudepohl	20
Lapp Insulator Company, Inc.	*
Leeds & Northrup Company	6
McCreary, Harold J.	24
Marine Rules	25
Metropolitan Device Corporation	*
Mineralac Electric Company	20
Minnesota Mining & Mfg. Company	*
National Carbon Company, Inc.	19
National Electric Products Corp.	14
New Products	16
Ohio Brass Company	4th Cover
Ohmite Manufacturing Company	*
Okonite Company, The	3
Owens-Corning Fiberglas Corp.	*
Phelps Dodge Copper Products Corp.	*
Polachek, Z. H.	24
Roebling's Sons Company, John A.	28
Roller-Smith Company	*
Rowan Controller Company, The	25
Sanderson & Porter	24
Sargent & Lundy	24
Science Abstracts	*
Sola Electric Company	*
Solar Manufacturing Corporation	12
Standards of AIEE	22
Taylor & Company, A. Y.	24
Trade Literature	14
Union Carbide & Carbon Corp.	19
United States Steel Corp. Subsidiary	15
United Transformer Corporation	25
Universal Clay Products Company, The	20
Warren, Howard S.	24
Westinghouse Electric & Mfg. Co.	21
Weston Electrical Instrument Corp.	*
White Engineering Corp., The J. G.	24
Wopat, J. W.	24
Wray & Company, J. G.	24

** See previous issues.*

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